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Continued Assessment of a High-Velocity Fabric Filtration System Used to Control Fly Ash Emissions

FabricsAmerica, Travelers Rest, SC

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

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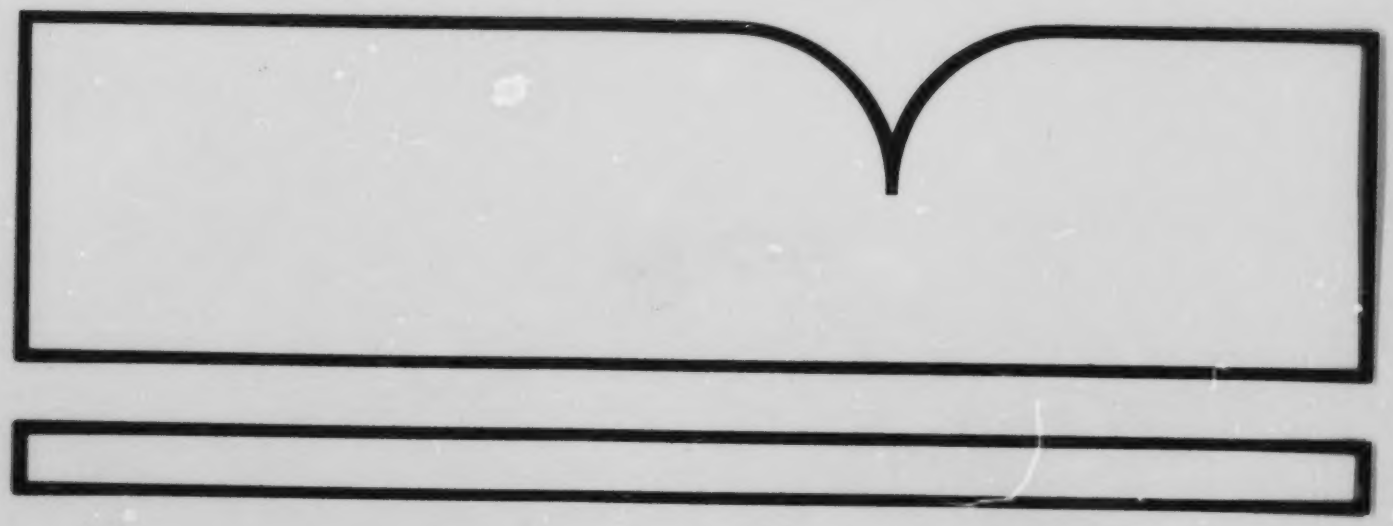

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March 1984

CONTINUED ASSESSMENT OF A HIGH-VELOCITY FABRIC FILTRATION SYSTEM USED TO CONTROL FLY ASH EMISSIONS

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16. ABSTRACT The report gives results of a full-scale investigation of the performance of a variety of filter media, to provide technical and economic information under high-velocity conditions (high gas/cloth ratio). The fly ash emission studies demonstrated that woven fiberglass fabrics and felts made from Teflon and Gore-Tex laminate were capable of meeting State emission code requirements at gas/cloth ratios of 4/1 to 6/1. The economic analysis showed that, in terms of annualized cost, the gas/-cloth ratio, initial bag cost, and bag life represent the greatest potentials for cost reduction. Pressure drop reductions can lower operating cost, but they have only secondary impact on annualized cost. The analysis compares the effects of incremental changes in bag life, gas/cloth ratio, and bag price on total annualized cost.

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Fabrics	Baghouses	11E
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ABSTRACT

This report gives results of a full-scale investigation of applying high-velocity fabric filtration to coal-fired boiler fly ash control. Initially, two filter systems were applied separately to two 60,000 lb steam/hr coal fired boilers. Due to a plant fire, the two filter systems were relocated: one system then served a 60,000 lb steam/hr boiler while the other controlled emissions from four smaller boilers.

Performance screening of a variety of semi-commercial filter media was performed in an attempt to determine the better techno-economic alternatives and also provide information on the possibility of operating such a system and filter media at higher filtering velocities. In addition to obtaining bag life and performance data, a comparative economic evaluation was done.

The bag life study indicated that the Teflon felt bags were very durable, and 4 years after start-up, 87% of the original bags were yet being utilized. The Huyck glass felt bags, while not tested for as long a period, also proved to be very durable. Heavier weight (26 oz/yd^2) woven glass was more durable than lighter weight (15 oz/yd^2) woven glass for this particular application and set of operating conditions. Nomex felt was found to fail rapidly, as had also been observed in the Kerr pilot study.[1] Gore-Tex bags, which had shown 10% failure in the first year of operation, failed at an accelerated rate in the second year and were changed out. The bags tested were Gore-Tex laminate on Gore-Tex woven backing. It is expected that the laminate on a different backing, such as felt, would provide longer life.

The emission studies demonstrated that Teflon felt, Gore-Tex laminate on a woven backing, and woven glass are all capable of meeting the State emission code requirements at gas-to-cloth ratios in the 4/1 to 6/1 range.

The economic analysis indicated that, in terms of annualized cost, the gas-to-cloth ratio and bag life represented the greatest potential for cost reduction. Bag cost could also be important if the cost reduction increment is greater than about \$1/ft^2 of cloth. The analysis indicates that, all else being equal, in order for a \$50 bag to compete with a \$20 bag, it requires four times greater life. Pressure drop reductions (1 in. increments), while reducing operating costs significantly, do not have as large an impact on annualized costs as do bag cost, gas-to-cloth ratio, or bag life, when considering increments of \$10/bag, 1 ft/min, and 1 yr, respectively.

A limited study of the merit of injecting an additive (Coaltrol X-1), in an attempt to reduce or eliminate acid dew point excursions, was added to the original program. The results of a short duration study indicated that such injection was effective in reducing pressure drop, metal corrosion, and fabric deterioration.

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I. INTRODUCTION

In 1973 Enviro-Systems & Research, Inc. was awarded an EPA contract for the purpose of determining the technical and economic feasibility of employing fabric filter dust collectors for fly-ash emission control, particularly, as applied to industrial boilers. Initially, the program was jointly funded by EPA, Kerr Finishing Division of Fabrics America and Enviro-Systems & Research, Inc. (ES&R). The plant, located in Concord, North Carolina, served as the host site for the program, and ES&R manufactured and installed the pilot facility. The pilot plant, installed on a slip stream of Kerr's No. 3 boiler, was sized to handle 11,000 ACFM when operating at a gas-to-cloth ratio (apparent filtering velocity) of 6/1. See Appendix A-1 for English to Metric conversions. This prototype facility was actually a two module commercial size unit (Enviro-Clean Model RAC-3) selected in order to minimize future scale-up problems. It is shown in Figure 1.

In order to evaluate fabric filtration as an acceptable means of dust collection with respect to coal-fired stoker boilers, the following had to be examined:

1. Pressure drop VS gas-to-cloth ratios for the various levels of cleaning-air volumes and bag material types.
2. Outlet loadings by size VS gas-to-cloth ratios for the various levels of cleaning air volumes and bag material types.
3. SO_2, SO_3, inlet loadings and particle size distributions.
4. Capital and operating cost comparisons for the different bag materials VS an electrostatic precipitator.
5. The boiler load for the various tests performed.

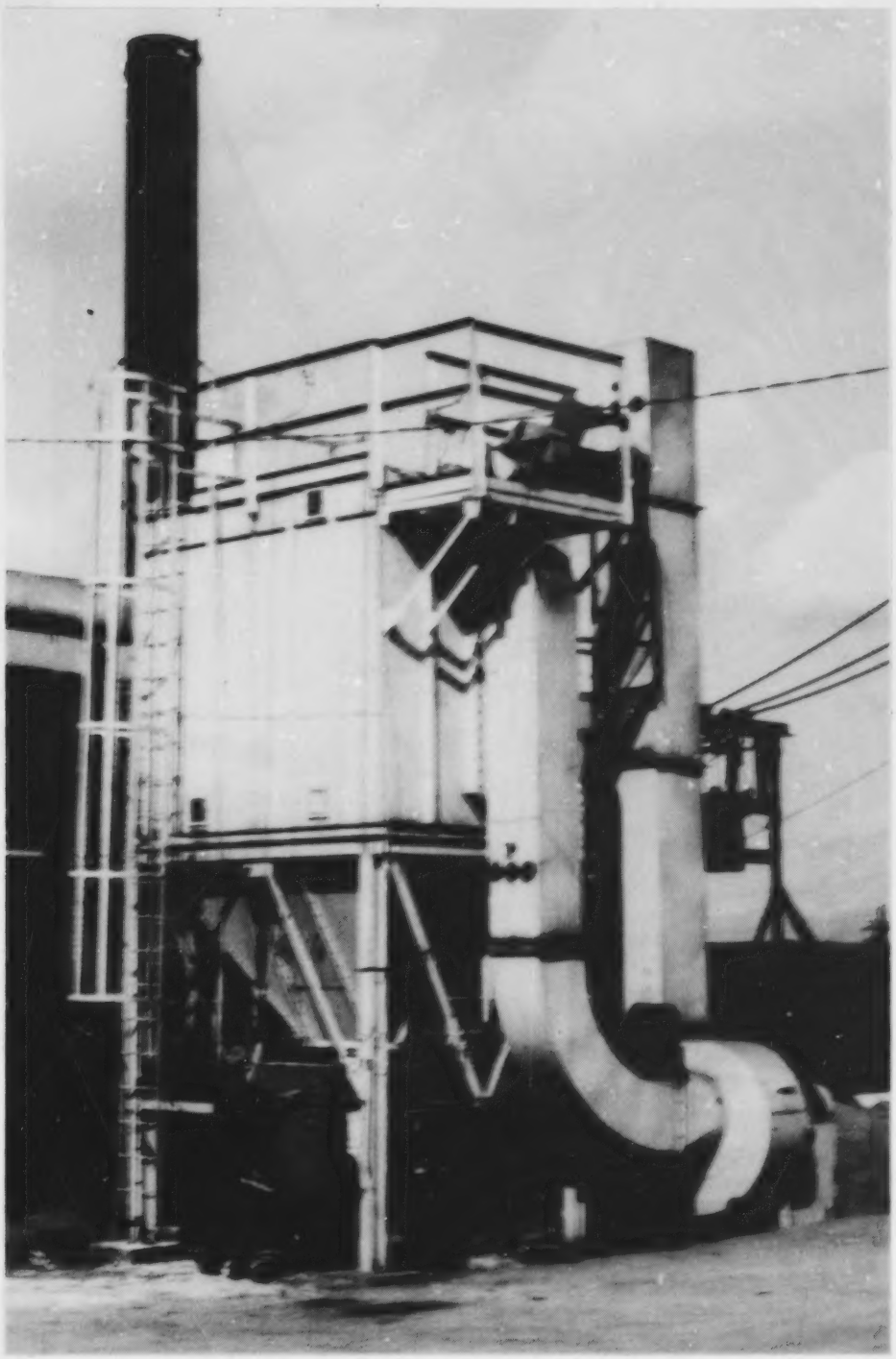


Figure 1

Kerr Pilot Plant

The filter media evaluated were Nomex (R) felt, Teflon (R) felt (2 styles), Gore-Tex (R) and Dralon-T (R). Fractional efficiencies were determined using an Andersen inertial impactor for the four filter media at three gas-to-cloth levels. The effect of cleaning gas volume on outlet loading and on pressure drop across the bags was evaluated.

In addition, studies of the effect of cleaning frequency and duration were conducted. The overall technical conclusion was that all four media tested could achieve outlet loadings meeting State code requirements regardless of the gas-to-cloth ratio (apparent filtering velocity). As the gas-to-cloth ratio increased, both the pressure drop and the outlet loadings increased.

Installed costs were determined and operating and annualized costs were developed from the operating characteristics obtained plus assumptions regarding bag life. They were then compared with precipitator costs developed for the same site. This pilot plant program and subsequent economic analysis led to the conclusion that fabric filter dust collectors are suitable for control of fly-ash from stoker fed coal-fired industrial boilers in terms of both dust removal efficiency and operating pressure drop. The main question left unanswered was what bag life is achievable with continuous service. If a two year bag life could be achieved, even with Teflon (R) felt (the most expensive bags), fabric filters appear economically more attractive than electrostatic precipitators for industrial coal-fired boiler applications.

The pilot plant program provided short term performance data including dust removal efficiencies and pressure drops for a number of filter media. These data and a preliminary economic analysis indicated that long term bag life and performance studies were warranted. The EPA thus decided to award

a contract for the full scale assessment of this approach to fly-ash control. The initial contract awarded to Fabrics America, with ES&R (subsequently ETS, Inc.) as the major sub-contractor, called for ES&R to design, fabricate, install and then operate the two fabric filter units for a period of one year. Contract options called for subsequent additional long term operation of the units in order to test other filter media and also to evaluate the device as a sulfur dioxide removal system.

The purpose of the assessment program was the testing of a full scale fabric filter system installed on an industrial size coal-fired stoker boiler. The baghouse system was to be operated and tested over the duration of the program to determine general operating parameters, bag life data and economic factors necessary for making techno-economic evaluations.

The objectives of the program are to demonstrate the feasibility of applying fabric filtration to industrial size coal-fired stoker boilers and to obtain the following data:

1. Comparisons of system performance (size efficiency and pressure drop) for various filter media including glass Teflon (R) felt and Gore-Tex (R).
2. Determination or prediction of fabric changes and fabric life for each fabric.
3. Capital, operating and annualized costs for the filter system for each fabric tested, and comparison with equivalent electrostatic precipitators.
4. A record of all pertinent boiler and filter system operating parameters.
5. Scale-up factors or deviations from the original work performed under EPA Contract 68-02-1093.

6. Characterization of the flue gas stream.

7. Characterization of the boiler fly-ash.

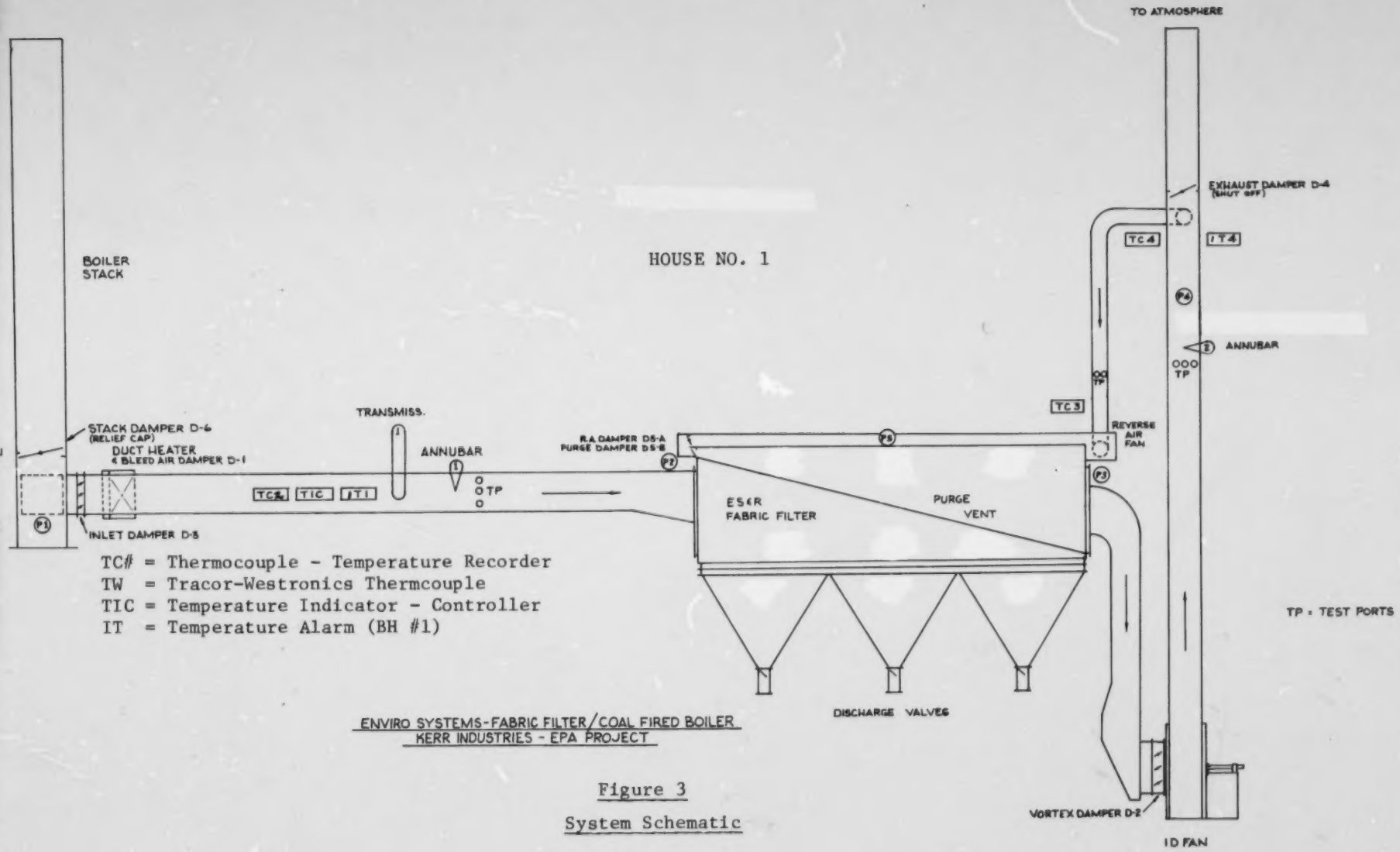
8. SO_3 reduction by chemical addition.

By January 1977, both baghouse units were operational (See Figure 2). Each boiler's emissions were separately controlled by a single baghouse system. Each of the two boiler-baghouse systems were designed to operate independent of each other (See Figures 2, 3 & 4). During 1977, baghouse Unit #1 employed Teflon (R) felt bags while Unit #2 used Gore-Tex (R) laminate on a woven Gore-Tex (R) backing. Due to failures of the Gore-Tex (R) bags during 1977, it was decided that while the Teflon (R) felt would continue to be evaluated in Unit #1, the Gore-Tex (R) bags would be removed from Unit #2 and this unit would be employed to evaluate other new filter bag types.

This present report discusses the results of work performed under this contract for the period January 1978 thru June 1981. On January 31, 1979, Kerr Industries' main manufacturing plant, located in Concord, North Carolina, was destroyed by fire. The boiler house and baghouses were consequently shut down, even though they escaped any damage. By April 1979, a decision had been made by Kerr to purchase a similar textile dye and finishing plant in Travelers Rest, South Carolina, rather than reconstruct one in Concord, NC. This plant in Travelers Rest had stoker fed coal-fired boilers which employed mechanical collectors for emission control. It was decided to move the baghouses from Concord, NC to Travelers Rest, SC, in order to upgrade the emission control system and also allow the EPA test program to be continued. By January of 1980, both baghouse units were installed and operating at Travelers Rest. The baghouse

Boiler & Baghouse System
Concord, NC

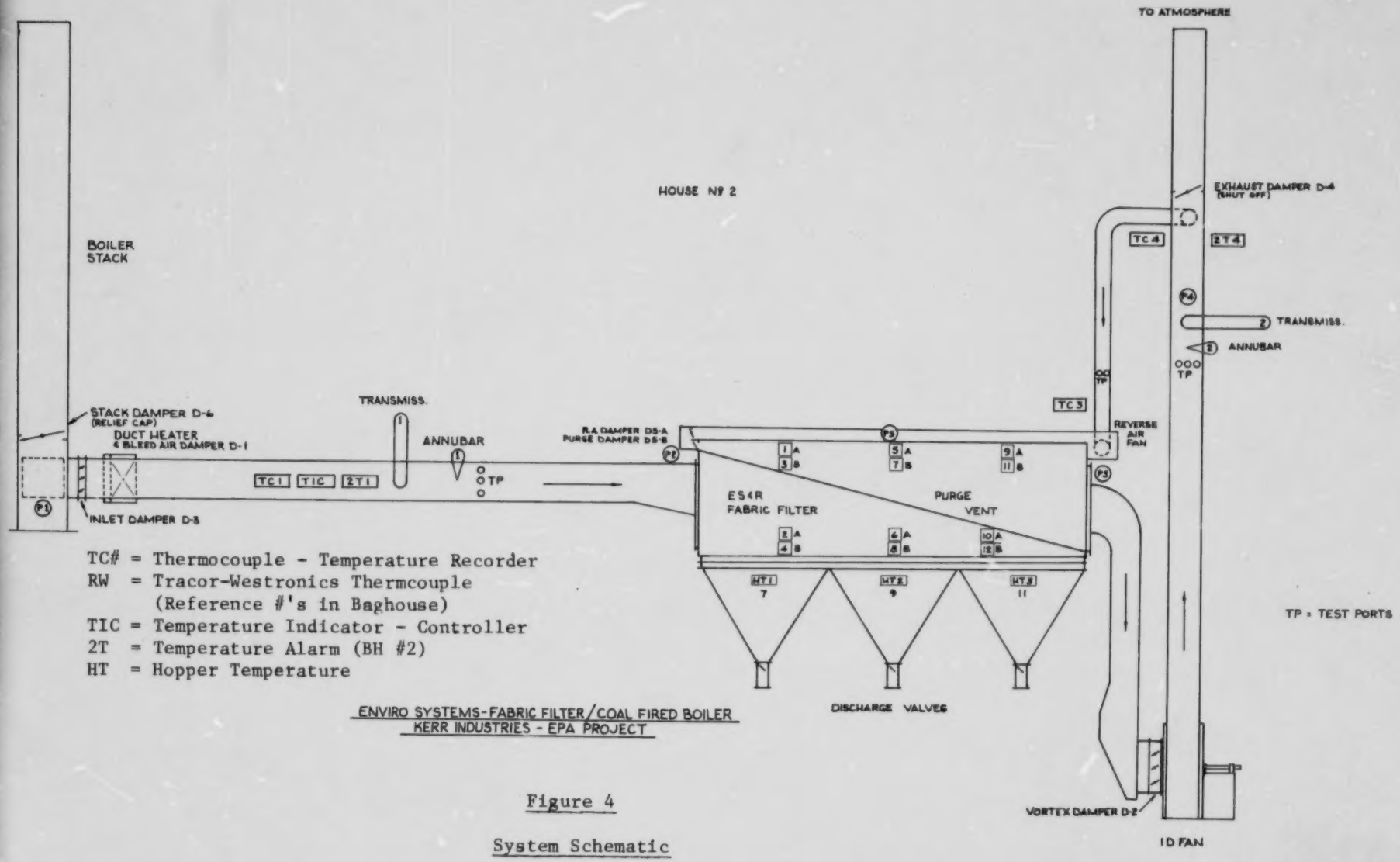
Figure 2



ENVIRO SYSTEMS-FABRIC FILTER/COAL FIRED BOILER
KERR INDUSTRIES - EPA PROJECT

Figure 3

System Schematic



TC# = Thermocouple - Temperature Recorder
RW = Tracor-Westronics Thermcouple
(Reference #'s in Baghouse)
TIC = Temperature Indicator - Controller
2T = Temperature Alarm (BH #2)
HT = Hopper Temperature

ENVIRO SYSTEMS-FABRIC FILTER/COAL FIRED BOILER
KERR INDUSTRIES - EPA PROJECT

Figure 4

System Schematic

system at the new location differed markedly from that at Concord, in that it services five boilers instead of two, the ductwork system is consequently different, and the baghouses were further sub-divided during the relocation.

In addition, Apollo Chemical provided equipment for dry additive injection and a study of acid neutralization was conducted at the Travelers Rest site along with the originally planned bag screening and high gas-to-cloth ratio studies.

II. CONCLUSIONS

Filter Media

- Teflon felt is extremely durable and will withstand removal, manual cleaning and long-term usage (greater than three (3) years).

- Woven glass can be used at the 5/1 gas-to-cloth ratios, but it appears that heavier weights (> 20 oz.) may be required in order to obtain long life.

- Gore-Tex PTFE laminate on PTFE woven backing is not structurally durable enough to make it a practical alternative. This does not rule out the possibility that the Gore-Tex laminate may be suitable on some other more durable backing.

- Huyck's felted glass proved to be very durable. The bags tested were not very flexible and therefore were somewhat difficult to install. These bags were made early in the commercial development of this product and inspection of subsequent material indicated it to be somewhat more flexible.

- Nomex is not suitable for use in this application and will fail in a matter of weeks.

- The Teflon felt, Gore-Tex and 26 oz. Woven Glass were capable of controlling emissions to the level needed to meet the State code. No emission performance evaluations were possible in the case of the other filter media tested for life.

Additive Injection

- The injection of Coaltrol into the inlet gas stream did result in significant reduction of free acidity.
- Reduced metal corrosion occurred due to the injection of Coaltrol.
- In some cases, the strength of certain filter medium types is retained at higher levels due to the injection of Coaltrol.
- Longer term studies are necessary to confirm the above.

III. RECOMMENDATIONS

In view of the meaningful information supplied by this program with respect to the relative commercial merit of the various filter media, it is recommended that the Kerr facilities be employed as a tool for a continuing evaluation of new or improved filter media for the control of fly ash from coal-fired boilers. Such information should prove to be of great value to industry as there remains a need for more reliable and less costly bags and it is anticipated that because of the potential size of the coal-fired boiler-baghouse market, fabric manufacturers will introduce innovative fabrics which will need to be field evaluated.

In addition, since there are two (2) independent baghouse units, it is further recommended that one of the two units be used in a study which attempts to operate the baghouse at higher gas-to-cloth ratios.

During such a program, one baghouse will be operated at air-to-cloth ratios of up to 10 to 1. Concurrently, the other baghouse could be utilized to evaluate new and/or improved fabric filters at currently acceptable gas-to-cloth levels (4/1 to 6/1). The purpose of these evaluations is the ultimate reduction of size and operating costs of baghouses used for control of particulate emissions. Other program objectives would be:

1. Obtain additional engineering data that would be generally useful for application engineering.
2. Obtain additional operating data and bag life data necessary in making techno-economic evaluations.
3. Evaluation of new fabric performance at filtering velocities ranging from 4 to 6 FPM. The performance of these fabrics will be compared with that of those currently recognized as state of the art.

4. Determination of filter media property changes as a function of on-stream duration. The foregoing determination is to be made for the following properties: tensile strength, burst strength, flex strength and air flow.
5. Evaluate the capability of operating the fabric filter system at higher filtering velocities (up to 10 FPM). Of particular interest will be the determination if high dust removal efficiencies and economically tolerable pressure drops are achievable.
6. Determination of the efficiency of removal for specific particle size ranges as a function of filter media on stream duration. This determination will be conducted on the Teflon felt house operating at the advanced A/C ratio.

IV. DESCRIPTION OF BOILERS

A. Concord Plant (Prior to January 1979)

The original location of the baghouses was at the Kerr Plant in Concord, N.C. The plant at Concord had two coal-fired water tube B&W boilers, each with a design capacity of 60,000 lb./hr. of steam. Both boilers employed Detroit Rotostokers containing dump grates. One baghouse system served each boiler.

The Travelers Rest plant, to which the two baghouses were moved after the fire at Concord, employed five (5) coal-fired boilers. Three (3) of the boilers had a design capacity of 22,500 lb./hr. of steam, while the other two (2) were 30,000 and 60,000, respectively. The relocated baghouses were set up so that one unit served the largest boiler and the other baghouse served the four (4) smaller boilers.

A detailed description of the boilers at the Concord plant may be found in EPA-600/7/79/094, pp. 8, 9. There was one boiler per baghouse unit, and the two boilers were identical. Each had combustion air preheat, so that the outlet gases from the preheaters (the inlet gases to the dust collectors) were cooled to 300-325^{o}F by the air to the boiler. The flue gases from each boiler passed through multicyclones and all collected solids were reinjected into the boilers.

B. At Travelers Rest (After February 1980)

System #1

The No. 1 baghouse is applied to a coal-fired Babcock & Wilcox boiler rated at 60,000 lbs. of steam per hour. A stoker grade coal (1½ in. X ¼ in.)

is fed to a spreader type Detroit Rotostoker from a central weighing scale manufactured by Richardson into three (3) stoker sections and onto a riser type dump grate. The design steam pressure is 250 lbs. per sq. in. gauge at saturation temperature with a feedwater temperature of 214°F from a mixing drum supplied by make-up water and steam returned lines. Normal maximum boiler operation provides 52,000 lbs./hr. steam at 160 psig and saturation temperature.

A Western Precipitator Corporation type 9VGR12, Model P59205B multi-cyclone is located on the boiler outlet but no economizer or fly-ash reinjection is provided. Instrumentation for automatic combustion control is provided and normal operation produces flue-gas characteristic of 450°F and 23,000 SCFM. The combustion air flow is provided by a combination of forced draft, overfire air, and induced draft fans. Ash handling is a manual labor process in which employees rake the ash out from underneath the boiler grates where it is loaded into wheelbarrows and dumped into the yards.

System #2:

The No. 2 baghouse is applied to a bank of four (4) coal-fired boilers manifolded into a 200 ft. natural draft stack.

The first three (3) boilers were constructed in 1928 by Walsh & Weidner Boiler Co., and are equipped with Combustion Engineering underfeed retort spreader type stokers and side dump grates. The boilers are rated at 22,500 lbs./hr. of steam at 250 psig and saturation temperature. The fourth boiler was constructed by Combustion Engineering in 1941 and is a sterling type equipped with a Combustion Engineering underfeed retort spreader type stoker and side dump grates. The steam flow rating is

30,000 lbs./hr. at 250 psig and saturation temperature. All four (4) boilers are provided with forced draft fans and normally operated two at a time providing steam at 160 psig and saturation temperature. The stoker size (1½ in. X ¼ in.) coal is fed to the stokers from the central weighing scales.

Outlet flue gas is directed to the baghouse from the boiler bank stack manifold at approximately 475°F and 25,000 SCFM with two (2) boilers operating.

Ash handling is a manual labor process as described in System #1 above.

V. DESCRIPTION OF BAGHOUSE

A. CONCORD INSTALLATION (Up to January 1979):

There are two separate, but physically identical, flange-to-flange fabric filters. Each unit contained 18 cells in two banks of 9 cells each, with each cell containing a 6 X 6 matrix of bags. The total number of bags in each unit was, therefore, 648 bags. Each bag was a nominal 5 inches (0.42 ft.) in diameter by 104 inches (8.67 ft.) in length. Total fabric area per unit was approximately 7400 sq. ft. A bag schematic is provided in Figure 5.

Unit 1 contains Teflon felt bags supported by cages. Unit 2 was initially filled with Gore-Tex polytetrafluoroethylene (PTFE) laminate bags which were later replaced with unsupported woven-glass bags. A major effort expended in the program was a search to find a method to prevent the unsupported bags from collapsing, by using different methods of installation and tensioning. None of these approaches proved to be successful. Each unit had three (3) hoppers and each hopper was divided in half.

There was one inlet duct to each unit and 18 cell outlet, feeding a common outlet duct existing each unit. Upstream of each unit was a damper. Downstream of each unit was an induced draft fan, with a vortex damper between the dust collector unit and the fan. Each fan discharged the flue gases into a stack.

In both units the dust was collected on the outside of the bags.

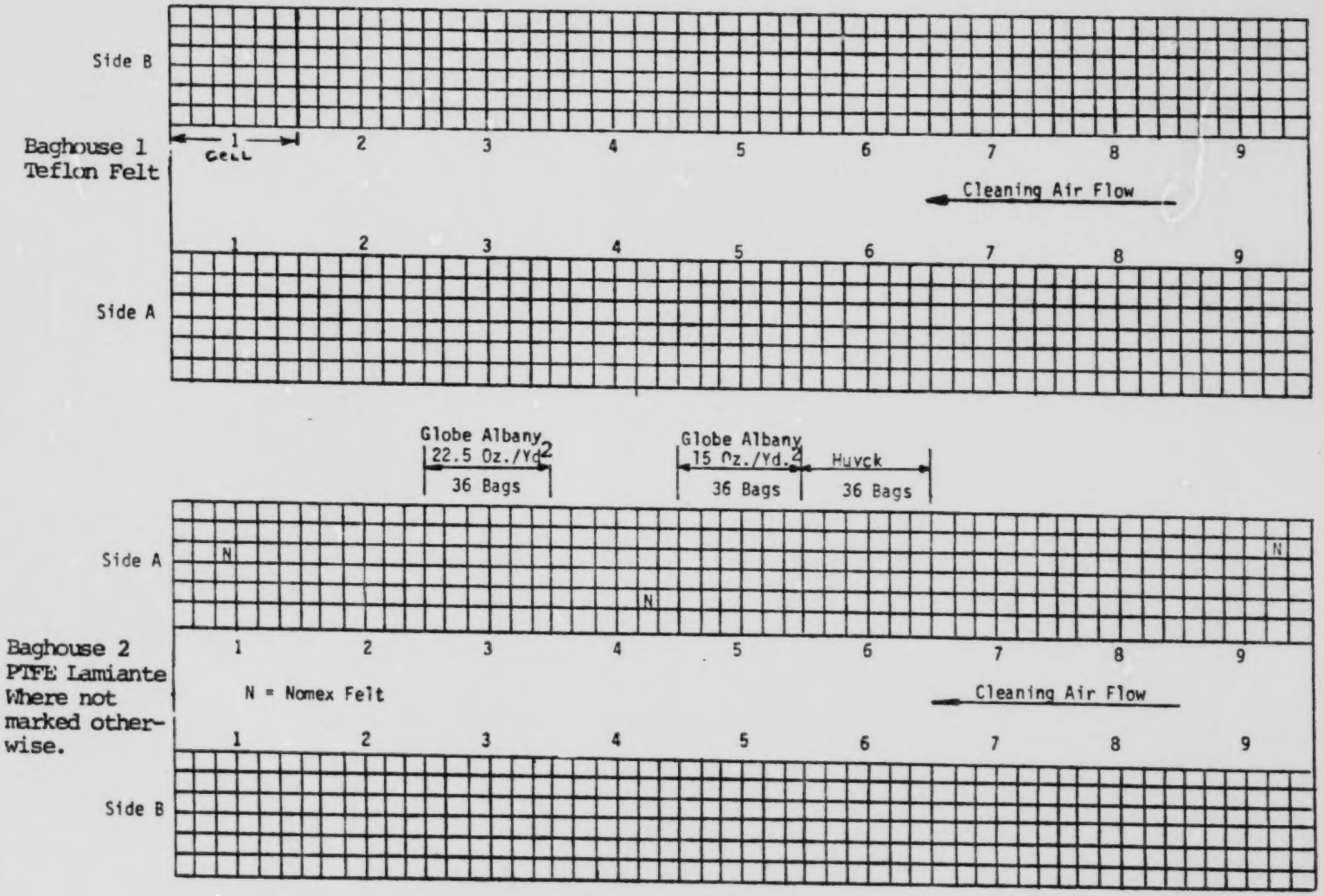
The frequently and duration of bag cleaning could be varied for both systems.

All system controls were automatic, with manual override possible. The pressure drop across both systems was controlled by controlling the inlet dampers upstream of the dust collectors.

Since the pressure drop across the system is a function of the gas-to-cloth

Figure 5

Schematic of Bag Arrangement



ratio (G/C ratio), cubic feet per minute of gas per square feet of filter media (FPM), either the G/C ratio was controlled by varying the inlet gas flow rate or the pressure drop across the system was controlled, by the same means.

The dust from the hoppers was dumped into drums, which could be weighed to determine the amount of dust collected in a given period of time.

B. TRAVELERS REST INSTALLATION (February 1980 to Present)

No modifications were made to the downstream dampers or fans when the pilot plant was moved to Travelers Rest. However, major modifications were made to the dust collectors and the inlet flow systems. Both collector units were sectionalized into six (6) sections of three (3) cells each, so that each bank of nine (9) cells contained three (3) sections.

Six (6) inlet dampers were installed in each unit, one (1) for each section, and one (1) outlet damper for each cell (18 total).

Unit 1 bags (Teflon felt) were cleaned both by pulse jets and reverse air, using only fresh air preheated to 350^{o}F. Unit 2 used reverse fresh air only, also preheated to 350^{o}F. Either a single section or an individual cell could be cleaned. As before, cleaning time and frequency could be varied.

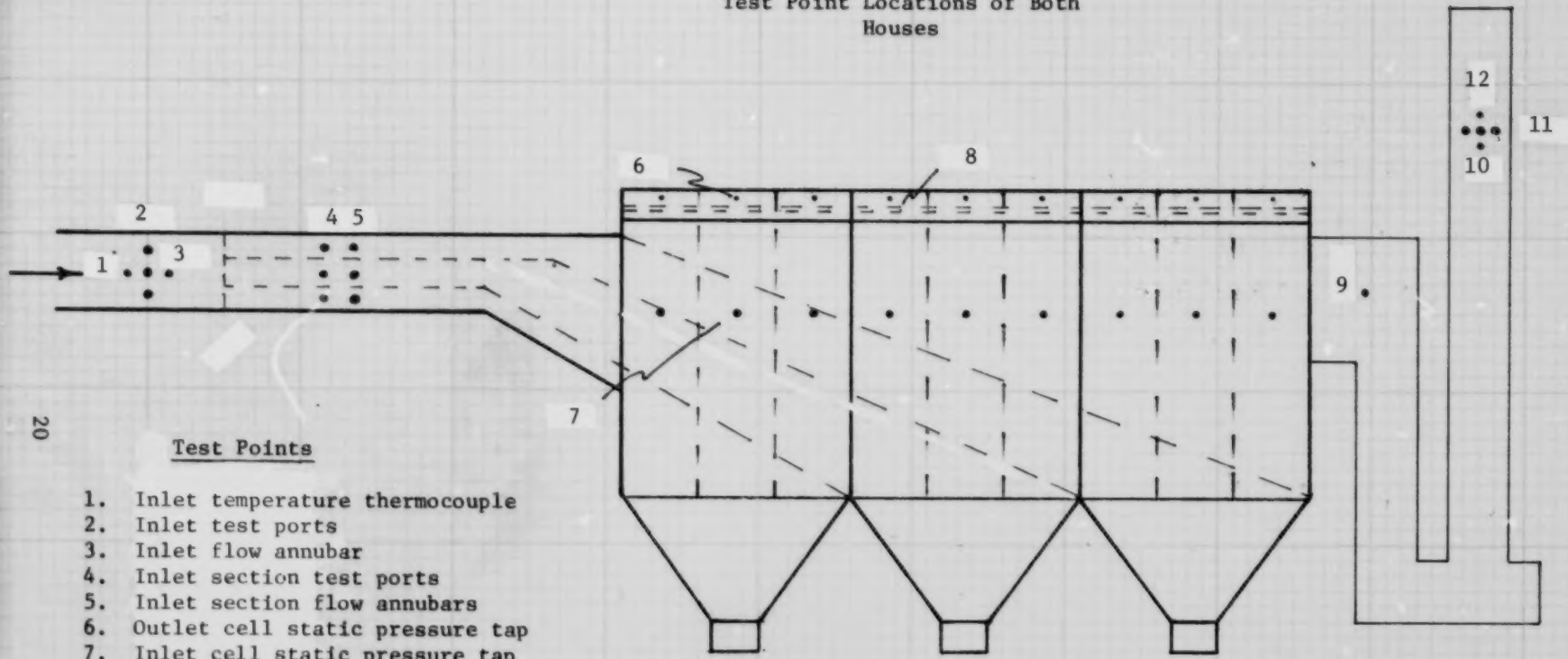
Unit 2 bags were cage-supported, woven-glass bags, unlike the operation at Concord, where cages were not used in Unit 2.

The dust from the hoppers was dumped into steel drums, which could be weighed to determine the amount of dust collected in a given period of time.

Figure 6 is a schematic diagram of the fabric filters system. The diagram also shows the test point locations of both baghouses.

Figure 6. Kerr Finishing Fabric Filters
System Schematic

Test Point Locations of Both
Houses



Test Points

1. Inlet temperature thermocouple
2. Inlet test ports
3. Inlet flow annubar
4. Inlet section test ports
5. Inlet section flow annubars
6. Outlet cell static pressure tap
7. Inlet cell static pressure tap
8. Outlet cell flow annubars
9. House outlet static pressure tap
10. Outlet temperature thermocouple
11. Outlet test ports
12. Oultet fan static pressure tap

VI. Description of Apollo Additive Program

The Apollo Chemical Company manufactures an additive called Coaltrol X-1 (hereafter referred to only as Coaltrol), a powdered solid, which according to the manufacturer, neutralizes SO_3, but does not react with SO_2. A series of tests was performed in cooperation with Apollo in which varying amounts of the Coaltrol additive were injected into the flue gas stream entering Unit 1 but not Unit 2. Samples of ash collected in Unit 1 were analyzed for free acid, reported as mg H_2SO_4 per gram of ash, during Coaltrol addition, as well as during normal operation without Coaltrol in order to establish the effectiveness of the Coaltrol additive.

During the period of Coaltrol addition, a limited program to evaluate the effects of the Coaltrol additive on fabric swatch aging and metal corrosion was performed. Two different metals and five different filter media were tested. The metals and filter media were hung in Units 1 and 2 only during the period of time when actual Coaltrol addition was occurring (207 hours total).

During Coaltrol addition, fresh unheated air was introduced into the flue gas stream upstream of the Coaltrol injection point in order to reduce the collector temperature below the dew point. As a result, inlet duct temperatures were reduced from the normal range of 450 - 475°F to the range from 200 - 385°F. However, by controlling the amount of diluent fresh air, the gas-to-cloth (G/C) ratios at the lower temperatures were held in the same range, about 5.0, as maintained at normal operating conditions.

A schematic showing the location of additive injection is provided in Figure 7. Dry chemical is fed into the inlet flue-gas stream of the No. 1 (Teflon) house by means of equipment consisting of a high volume low pressure compressor/blower, a pyramid hopper, a screw type feeder unit and a

flexible conveying line.

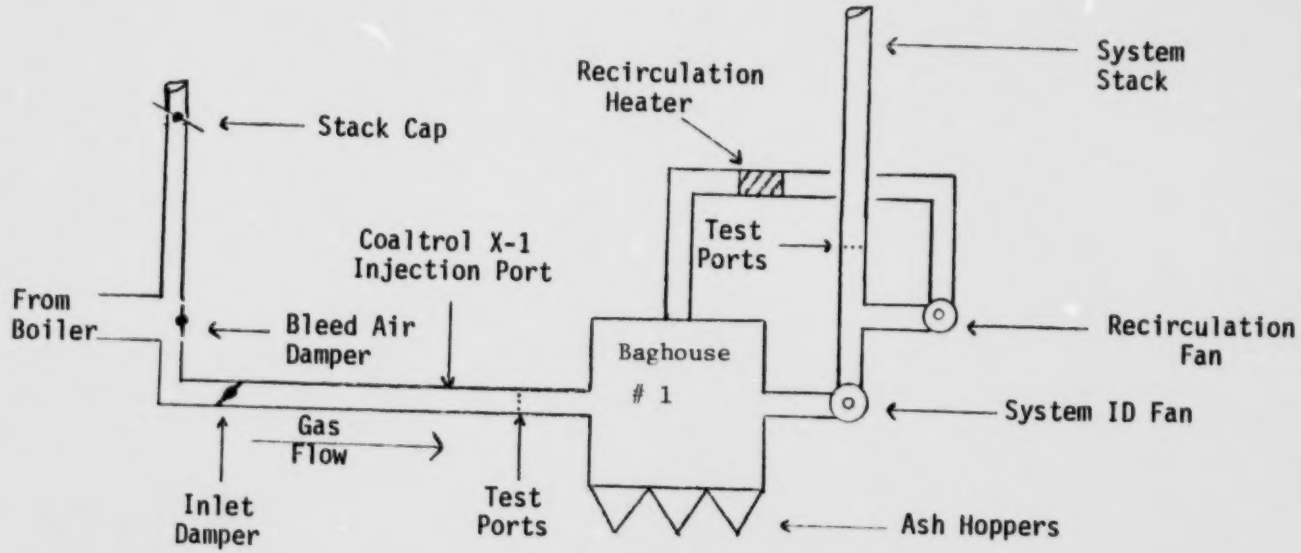
The dry chemical is manually loaded with 30-lb. drums into the pyramid hopper of approximately 10 cu. ft. capacity outfitted with a vibrator. The screw type feeder unit with variable speed control delivers the dry chemical from the hopper to the flexible conveying line at a pre-determined rate. Air from the compressor/blower unit transports the chemical to an injection point 50 ft. upstream of the baghouse, to allow for adequate mixing. The injection point is located on the top of the duct and 6 in. from the duct wall. A pipe with a 45^{o} cutaway facing down-stream allows free injection of the chemicals without plugging and assures the line is under negative static pressure when the equipment is off-line.

Figure 7

Kerr Travelers Rest

Filter House Schematic

SHOWING LOCATION OF COALTROL INJECTION



VII. RESULTS AND DISCUSSION

A. GENERAL BAGHOUSE OPERATION:

The operation of the Kerr baghouses from January 1978 to January 1979 at Concord, NC yielded a great deal of information about desirable and undesirable operating procedures and about changes in structural design that had to be made to maximize performance and extend life of the control equipment. Pressure drop problems were gradually overcome during this period, changes were made in design of controls and other parts of the physical plant, and stable operation was achieved as the maintenance program was upgraded. By the end of 1978, both houses were working well. Unfortunately, just as this desirable level of performance was within reach, a fire destroyed the Kerr manufacturing plant on January 31, 1979. Kerr inventory and boiler houses were not affected, nor was the baghouse facility involved. The decision was made to relocate the baghouses to the Kerr plant at Travelers Rest, SC, and the houses were fully operational by February 1980, after modifications were made to sectionalize the two dust collector units.

MAJOR OPERATING PROBLEMS, THEIR CAUSE(S) AND CORRECTION

HIGH PRESSURE DROP AT CONCORD INSTALLATION (Before January 1979)

Possible causes:

1. LOW TEMPERATURE EXCURSIONS

It was found that using the auxiliary burners to keep inlet temperature at about 340°F produced more stable pressure drops, but location of the burners too close to the inlet gas stream caused frequent burner malfunctions. In December 1979, ductwork was extended out of the gas stream to correct this problem, and the result was reliable burner operation requiring only incidental maintenance. However, weak electrical signals from the burner controllers

sometimes caused shutdown of the units because safety limits were exceeded. Discussion of this problem with a representative of the burner manufacturer indicated that the length of the controller wires was excessive. A newer model controller was available that would provide adequate signal strength, and two were installed on the burners.

In January 1979, the blower motors on the burner fans of both units were found to be rotating in the wrong direction. This was corrected and the flame pattern at the burners improved immediately.

High winds, cold weather, and heavy rainfall appeared to have direct effects on house pressure drop. It seemed that keeping inlet temperature at about 340°F and closing baghouse stack caps partially alleviated the effect of rainfall on pressure drop. Both houses were operated with stack caps open when boiler loads exceeded the capacity of the system fan. With the stack cap open, the vortex damper also was open, and the system fan would pull maximum amount, not just enough to balance the boiler emissions. Misuse of this operating device by boiler crews, usually at night, caused the baghouses to experience dew point excursions.

2. DUST CAKE BUILDUP

Cleandown of the Teflon felt bags, house No. 1, seemed to be largely dependent on the supply of cleaning air, while position and tensioning of bags in house No. 2 as part of an improved reverse air plenum.

In January 1978, the mechanical efficiency of the reverse air fan was calculated to be about 15%, versus a design value of about 70%. This was due to system inability to pull enough air into the fan because of the duct design. Air scoops were installed to direct system fan air into the reverse air inlet duct and this change solved the problem.

Despite repairs to the two air compressors in September and October 1978, there was not sufficient compressed air to provide good cleaning. In addition, condensation in compressor after-coolers during cold weather caused system shutdown. Enclosing the compressors and after-coolers eliminated this problem. However, moisture still was observed in valves and solenoids associated with the vortex dampers, so the vortex damper controllers were also enclosed.

Even after improvements and repairs to the reverse air cleaning system, it was felt that additional cleaning energy was desirable. A pulse jet system was considered, and in order to gauge its effect on house pressure drop, a portable pulse jet unit was used to provide periodic off-line cleaning of house No. 1. Immediate improvement in cleandown resulted with each cell of bags producing about one barrel of light, non-viscous fly ash. About 1/2 in. of heavily pearled cake covered the bags before cleaning, and pressure drop was about 10 in. W.G.; after pulse jet cleaning, house pressure drop was about 3 in. W.G. This excellent cleaning performance made a permanent pulse jet system technically attractive, and so such a unit was installed on house No. 1 during the July shutdown. Immediate improvement was noted in reduced cake thickness on the Teflon bags. A test devised for evaluating cleaning effectiveness as a variable in house pressure drop consisted of comparing forward and reverse pressure drops with each house both on and off-line, after cleaning one cell by pulse jet, the others by reverse air. Because of parallel operation of the cells, no significant difference in forward pressure drop during normal operation was observed between the pulse jet cleaned cell and the other cells. However, in the reverse direction, with the system off-line, only one-half the pressure drop was seen in the pulse jet-cleaned cell compared with

the other cells. This off-line reverse air/pulse jet test determined the effects of variables on pressure drop.

3. GRAIN LOADING

In order to try to gauge the effect of inlet grain loading on pressure drop, it was decided that during the July 1978 shutdown, the disassembled multicyclone on boiler No. 1 would be rebuilt with a 100% reinjection rate of fly ash into the boiler. This modification allowed for the comparison of removal efficiency data as well as analysis of fly ash characteristics. The results of analysis of fly ash samples collected in December 1978 are presented below. They indicate that boiler combustion efficiency improved as a result of fly ash reinjection via the multicyclone.

	%C	%H	% Loss on Ignition (Weight loss assumed to be C)
Baghouse No. 1*	21.36	0.08	22.25
Baghouse No. 2	32.52	0.24	34.91

The effect of the multicyclone on particle size distribution at the baghouse inlet appeared to be a reduction in the concentration of particles larger than 0.6 μ in diameter.

Use of wet or frozen poor quality coal throughout 1978 finally resulted, in January 1979, in the necessity of grate cleaning on a three hour schedule, rather than the usual four hour cycle. The process of grate cleaning presented the baghouses with increased grain loading and varying temperatures, and quite often caused shutdown of the baghouse.

The level of excess air from the boilers was suspected to be too high, causing excess fly ash carryover, more unburned carbon, and higher than normal flue gas temperature for a given boiler load. A representative of Detroit

* Baghouse Nos. 1 and 2 control emissions from boilers Nos. 1 and 2, respectively.

Rotostoker visited Kerr in August 1978 to discuss the problem of excess air from the boilers. His recommendations for the Kerr boilers' operating ranges were:

Boiler Load, Lb./Hr.:	Excess Air, %:
60,000	25-30 (4.5-5% O_2)
20,000	75 (9% O_2)

A measurement taken at Kerr was 73% excess air (9% O_2) at 41,000 lb./hr., which was close to the right amount. At Kerr, the induced draft fan was set manually to keep -0.1 in. H_2O pressure in the boiler and was seldom adjusted, even when boiler load changed. It appeared that a relatively constant forced draft air level produced a constant baghouse inlet volume, regardless of boiler load. The Rotostoker representative concluded that high excess air might be a factor in baghouse pressure drop problems at Kerr. He recommended that the forced draft fan be changed to follow boiler load automatically. It was decided to equip boiler No. 1 with controls for automatic forced draft adjustment. While excess air levels were reduced following installation of the controls, the automatic adjustment appeared to cause immediate baghouse pressure drop fluctuations. Operation of house No. 1 continued to be a pressure drop of 7.5 to 10 in. W.G. after that, even under the best of operating conditions.

Ash storage in the hoppers appeared to cause an increase in house pressure drop, probably because of particle re-entrainment. Other problems associated with ash storage in the hoppers included condensation on the ash and the subsequent difficulty in dumping it, plugging of hoppers, and the danger of fire. The lack of automated fly ash disposal at Kerr was a continual source of difficulty.

4. BAG TENSIONING

TEFLON FELT; There were no tensioning problems in house No. 1. During March 1978, leaks were found in five (5) cells of the house as a result of bags which had fallen slightly or completely below the tube sheet. An improved bag securing system, consisting of the use of bottom bag positioners, was installed on the house during the July shutdown.

HOUSE NO. 2: The failure of Gore-Tex bags, which had been installed in house No. 2 at start-up in 1976, resulted in the outfitting of sixteen (16) cells with Globe Albany 22.5 oz./sq. yd. woven glass bags in August 1978. The woven glass bags were of cageless design, including anti-collapse rings which required tensioning. The tensioning system would have been able to accommodate stretching a minimum of 4-5% of bag length, and would have to allow for individual bag tensioning since all bags did not stretch the same amount. The collector was not originally designed for this type of bag; tensioning had to be done from the bottom, in a location where maintenance was difficult. There were several false starts in reaching a solution to tensioning problems, resulting in improperly tensioned bags for extended periods of time. This caused under-tensioning, leading to bag collapse and higher pressure drop, over-tensioning, leading to loss of good flow and cleaning characteristics and pull-out of bags from the tube sheet. It is likely that the glass bags experienced high G/C ratios than were routinely measured, and still there was little bag abrasion, even with constant handling during tensioning, and frequent dew point excursions.

On February 1, 1979, the day after the fire that destroyed the Kerr manufacturing plant, power was reconnected to both baghouse units to allow manual preheat and purge cycles so that corrosive effects on the units could

be minimized. Baghouse and boiler operation and maintenance would go on while decisions about re-building or relocating were made. Kerr is now located in Travelers Rest, South Carolina. Kerr agreed to allow ETS to relocate the baghouse facility at Travelers Rest, and to continue the evaluation.

The interval between the fire and the move to Travelers Rest made it possible for ETS to implement system design changes and to upgrade maintenance. Investigation of SO_x control systems also was on-going during this period. During March 1979, the Teflon house was operated for four days to determine the effect of a hopper-by-hopper pulse jet cleaning procedure. It was found that by utilizing this off-line cleaning, the house could be operated at higher G/C ratios than was previously possible.

B. Flue Gas and Dust Evaluations

The tests performed on baghouse inlets and outlets at Kerr consisted of EPA Methods 1-5 (substituting a medium porosity alundum thimble for a heated glass filter in some tests), and particle sizing tests using Andersen and Brink cascade impactors. In addition, some parameters were continuously monitored by recorders in the baghouse facility control room. Only a limited amount of emission data was obtained during this program. The data acquisition program required that the units be operated in a relatively stable mode and unfortunately shortly after the desired stability was achieved at Concord, N.C., the plant was destroyed by fire. Relocation of the baghouses to the new location resulted in a repeat of the unstable operation and the need once again to determine the stable operating mode.

In January 1973, prior to the pilot study, the North Carolina Air Quality Division performed tests on two consecutive days to determine the quantity of particulate emissions from the stack of Kerr's Boiler No. 2. Orsat analysis of the stack gas showed the oxygen content to be 10%, carbon dioxide to be 9.5%, and no carbon monoxide. Each boiler was assigned an emission factor of 0.36 $lb/10^6$ BTU, based on design BTU input. This factor multiplied by the actual BTU input, which was derived from actual steam production rate and the generating efficiency of 77%, yielded allowable emission rates of 25.1 lb./hr. and 27.8 lb./hr. for the two tests; actual emission rates of the two tests were 131.4 lb./hr. and 135.6 lb./hr., respectively.

In order to compute total particulate emissions from each house, and compare them with the emission rates allowed by the State of North Carolina, results of Andersen tests were used for outlet loadings. The calculated

emission rates, shown in Figure R-1, indicate that emissions from all three filter media generally were in compliance with air pollution regulations. The impactor test results used to develop Figure R-1 are provided in Tables R-2 and R-3. Table R-4 indicates the inlet characterization obtained by Method 5 tests. In the case of Teflon felt and Gore-Tex, the Method 5 results also indicated that these two filter media met the State compliance requirements.

The results of Method 5 tests are given in Table R-1. The lowest outlet emission measured was 0.0087 gr/SCF. This was obtained on Teflon felt when the house was located in Concord, N.C. The inlet grain loading averaged about 0.5 gr/SCF for House #1 and about 0.1 gr/SCF lower for House #2. While the Gore-Tex bags were undamaged, their emission performance was similar to that of the Teflon.

Characterization of the particle size distribution at the outlet of each house showed that each medium (Teflon Felt, Globe Albany 22.5 oz./yd.^{2} Woven Glass, and Gore-Tex/Gore-Tex PTFE Laminate) emits essentially the same range of particle sizes (Table R-3 and Figure R-2.) All comparisons were made at a G/C ratio of 6/1 ACFM.

A multi-cyclone was installed upstream of the Teflon house in July, 1978. It was placed just after the air preheater but prior to the baghouse system inlet damper. Particle size data, obtained both before and after installation of the cyclone show some reduction, after installation, in the concentration of larger particles. These results are shown in Figure R-3.

A typical coal analysis is presented in the appendix, along with tables and figures for the individual Method 5 and cascade impactor runs.

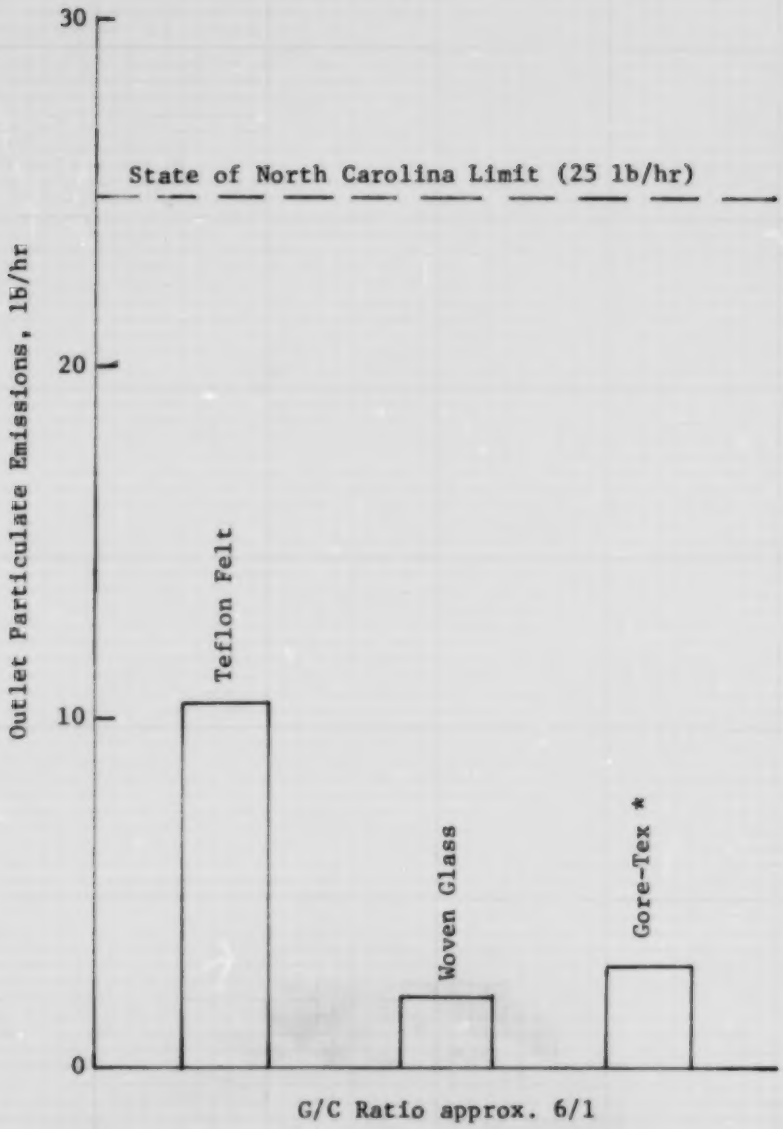


Figure R-1

Performance of Three Filter Media in
Controlling Particulate Emissions from a Coal-Fired Boiler

* Data from 1977; no probe and nozzle washes were collected.

Figure R-2

Outlet Particle Size Distribution for Each of Three Filter Media
(G/C Ratio 6/1)

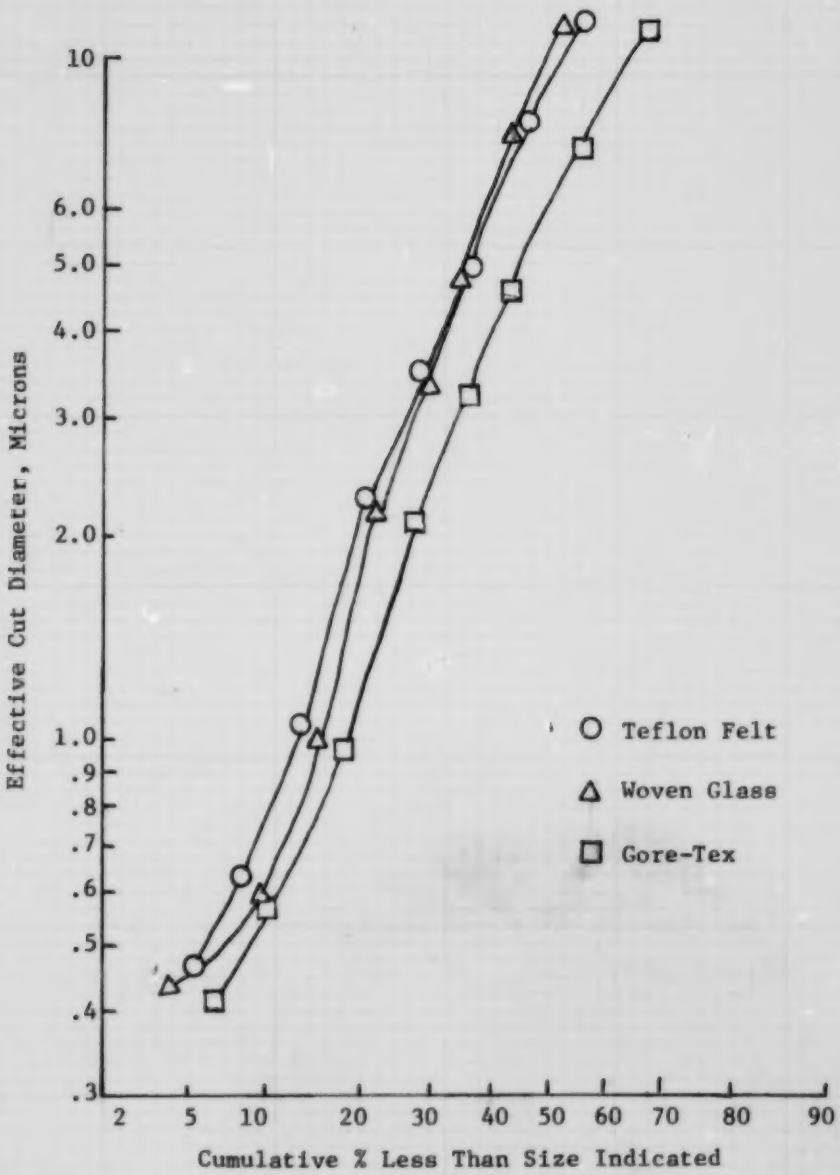


Figure R-3

Inlet Particle Size Distribution

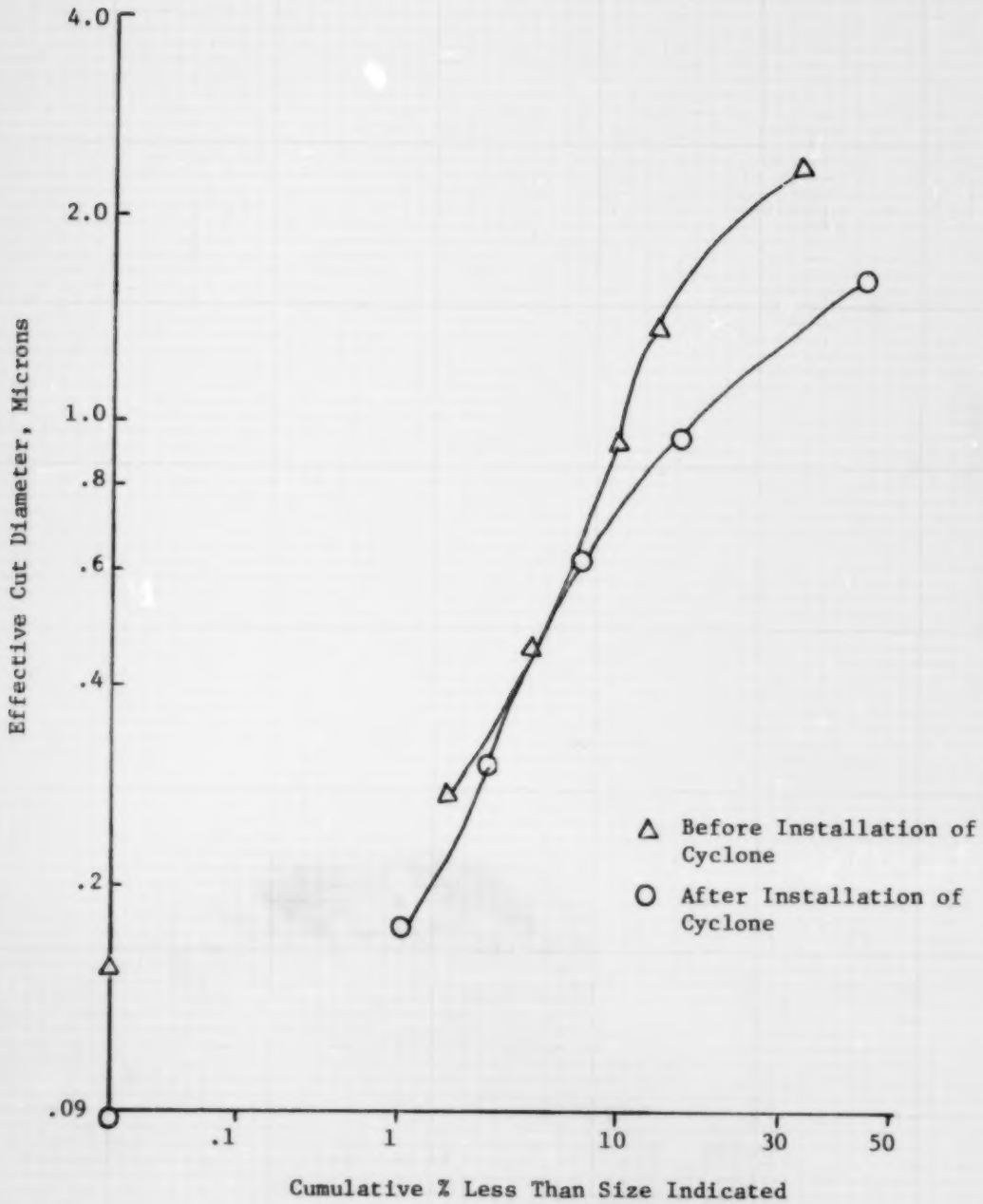


TABLE R-1

HOUSE #1 METHOD 5 EMISSION TEST RESULTS

HOUSE # *	PLANT LOCATION	TEST LOCATION Inlet Average (gr/SCF)	TEST LOCATION Outlet Average (gr/SCF)	EFFICIENCY %
1	Concord	0.5013	0.0330	93.4
1	Travelers Rest	0.5252	0.0679	87.1
2	Concord	0.4272	0.0605	85.8
		Inlet Average (gr/SCF)	**Lowest Outlet (gr/SCF)**	
1	Concord	0.5013	0.0087	98.3
1	Travelers Rest	0.5252	0.0117	97.8
2	Concord	0.4272	0.0263	93.8

* Test results given are for Teflon Felt in the case of House #1 and Gore-Tex in the case of House #2.

Table R-2

Inlet Characterization by Brink Impactor
(Particle Sizing)

Test No.	Date	Stage	Particle Diameter, Microns	Cumulative % Less Than Size Stated	Loading, Grains/DSCF
TEFLON FELT HOUSE					
68	11/15/78	1	1.59	43.18	.264
		2	.92	15.25	.130
		3	.61	6.70	.040
		4	.30	2.65	.019
		5	.17	1.00	.008
		6	.09	0.00	.005
				TOTAL	.465
GLOBE ALBANY 22.5 OZ./YD.^{2} WOVEN GLASS HOUSE					
71	1/19/79	1	2.30	31.57	1.655
		2	1.34	12.84	.453
		3	.90	9.37	.084
		4	.45	4.28	.123
		5	.27	1.74	.062
		6	.15	0.00	.042
				TOTAL	2.419
73*	1/19/79	1	2.31	61.93	.245
		2	1.34	34.62	.175
		3	.90	25.39	.059
		4	.45	20.77	.030
		5	.27	13.47	.047
		6	.15	0.00	.086
				TOTAL	.642

* No probe and nozzle washes were collected.

Table R-3

Outlet Characterization by Andersen Impactor*
(Particle Sizing)

G/C Ratio 6/1

	Teflon Felt			Woven Glass			Gore-Tex **		
Stage	Diameter,[1] Microns	Loading,[2] Grains/ dscf	Cumulative[3] %	Diameter, Microns	Loading, Grains/ dscf	Cumulative %	Diameter, Microns	Loading, Grains dscf	Cumulative %
1	>11.40	.01503	55.70	>10.89	.00319	51.96	>10.43	.00304	66.41
2	8.00	.00348	45.45	7.64	.00062	42.62	7.32	.00102	55.14
3	4.93	.00326	35.84	4.70	.00057	34.04	4.51	.00116	42.32
4	3.47	.00271	27.85	3.31	.00041	27.86	3.17	.00063	35.36
5	2.26	.00266	20.01	2.15	.00043	21.39	2.06	.00075	27.07
6	1.04	.00230	13.23	.99	.00044	14.76	.95	.00085	17.68
7	.63	.00174	8.10	.59	.00035	9.49	.57	.00069	10.06
8	.46	.00101	5.13	.43	.00036	4.07	.41	.00035	6.19
Back-Up Filter	<.46	.00174	-	<.43	.00027	-	<.41	.00056	-
	TOTAL	.03393		TOTAL	.00664		TOTAL	.00905	

[1] Mean Effective Cut Diameter

[2] Mean Loading Per Stage

[3] Mean Cumulative % Less Than Size Indicated

* Mean results of tests during 1978.
** No Probe and Nozzle Washes Were Collected.

Table R-4

Inlet Characterization

(Source Testing, EPA Methods 1-5) *

	Baghouse #1 (Teflon Felt)	Baghouse #2 (Woven Glass)
Dry Gas Composition		
CO_2 (%)	5.8 (Range 4.8 - 6.5)	5.5 (Range 4.2 - 5.8)
CO (%)	.1 (Range 0 - .3)	.2 (Range .2 - .3)
O_2 (%)	14.0 (Range 12.9 - 14.8)	14.1 (Range 13.6 - 14.6)
N_2 (%)	80.1 (Range 79.3 - 80.5)	80.2 (Range 80.0 - 80.3)
Moisture (%)	4.3 (Range 2.1 - 6.2)	3.3 (Range 3.2 - 3.4)
Molecular Weight of Dry Gas (amu)	29.49 (Range 29.36 - 29.61)	29.44 (Range 29.42 - 29.47)
Temperature (^{o}F)	316 (Range 296 - 374)	350 (Range 340 - 360)
Gas Volume (ACFM)	35,709 (Range 32,467-39,330)	39,724 (Range 37,988-41,461)
G/C Ratio	5.1/1 (Range 4.6 - 5.6/1)	5.6/1 (Range 5.4 - 5.9/1)

* Mean results of tests during 1978.

C. Filter Media

The filter media used in the baghouses at Kerr included:

Teflon(R) felt, style 2663, a tetrafluoroethylene (TEE) fluorocarbon:

Gore-Tex(R) (GT), expanded Teflon (Polytetrafluoroethylene-PTFE) laminate

Globe Albany 22.5 oz./yd.^{2} woven glass with Q-78 finish (GA-22.5);

Globe Albany 15 oz./yd.^{2} woven glass with Q-78 finish (GA-15);

P&S 26 oz./yd.^{2} woven glass with 10% Teflon B finish (PS-26);

Nomex felt, a high temperature-resistant nylon fiber (polyamide); and

Huyck experimental felted glass.

Table X lists the specifications of these fabrics. Table XI shows the numbers and causes, where known, of filter bag failures at Kerr from start-up in 1976 through May of 1981.

Teflon felt has been used exclusively in Baghouse No. 1 at Kerr. These bags proved to be very durable and able to withstand repeated manual removal and vacuuming. It was not until after about a year and one-half of service did any appreciable failures occur. After four (4) years of operation (less about 8-months operation due to fire), a total of 85 of 648 bags (13%) were replaced. This performance is somewhat remarkable in light of the experimental nature of the program which resulted by design in the exposure of these bags to a variety of severe operating conditions. When House No. 1 was relocated to Travelers Rest, the Teflon bags were left in place in the belief that these bags could withstand the move. This proved to be a valid assumption. Many factors influenced the replacement rate, including acid dew point excursions, high differential pressure across

the bags, manual cleaning, and high gas-to-cloth ratios.

Manual cleaning involved removal, industrial vacuuming, and reinstallation of the bags. This cleaning was performed on all of the Teflon bags during February 1978. Just after cleaning, the G/C ratio in House No. 1 was 3.5/1 but rose to 4.5/1 by the end of the month. In May, about 3% of the Teflon bags showed minor damage at the top restraining rings as a result of cleaning and handling.

The Teflon felt bags showed a characteristic dust collection pattern: less dust covered the bags at the bottom than at the top.

Of the thirteen (13) failed Teflon bags removed during May, only one had an obvious hole. E. I. duPont Nemours & Co., Inc. tested the failed bags and found that their physical properties were relatively unchanged.

In July the Teflon bags again were removed, cleaned and reinstalled. Some of the bags were washed on the outside with a high pressure hose, for about ten (10) minutes per bag. They were dried and tested for permeability using a Frazier Air Permeability Machine. Permeability recovery was 21 $ft.^3/min./ft.^2$, up from a permeability when dirty of 2 to 4 $ft.^3/min./ft.^2$. Table XII is a listing of the results of all permeability tests run during 1978-79 on filter media used in the baghouses at Kerr Industries. The Teflon bags tested in February 1979 showed such different permeabilities on retesting because of very specific leaks discovered when duPont analyzed physical properties of some of the bags.

The Teflon bags were manually cleaned during September. House No. 1 dumped ash uniformly during the month despite generally heavy boiler loads of 45,000 to 60,000 lb./hr. The persistent pressure drop problem experienced by both baghouses during 1978 prompted a decision in October to put the Teflon

house in the cleaning mode one day per week.

Baghouse No. 2 was initially outfitted with Gore-Tex PFTE laminate bags. One complete cell (36 bags) was replaced with Huyck experimental glass bags in March 1977, while another cell was outfitted with Globe Albany 22.5 oz./yd.^{2} woven glass bags in May 1977. Neither of these cells has shown failure to date.

The Gore-Tex bags, which had shown a replacement rate of 10% during the first year's operation, began to fail at an accelerated rate and in August 1978 were completely replaced with 26 oz./yd.^{2} woven glass bags with Teflon B finish. It is believed that a large number of the Gore-Tex failures may be attributed to damage caused by manual cleaning and handling of the bags. The 26 oz. bags held up well for the six months of operation prior to the fire. After being in operation at the Travelers Rest site for about three (3) months, numerous failures occurred. It is believed that the cleaning, handling and storage of these bags during the relocation was the primary cause of failure. After the failure of the 26 oz. bags, a decision was made to install 15 oz. woven glass in combination with mesh cages. While the prior experience at Kerr indicated better life with heavier weight glass, some commercial success when mesh cages with 15 oz. glass and pulse jets were used, led to the above decision.

A representative of Huyck Research Center tested the Huyck glass and Gore-Tex bags in January 1978. Findings were that Huyck bags resisted flow slightly more than Gore-Tex. In September, the Huyck bags were observed to be heavily caked and pearled. The 36 Huyck felted glass bags tested proved to be very durable. These bags were in place for more than three (3) years and visual inspection indicated no failures. These bags were left in place during the relocation due to the difficulty of removal and replacement of

this stiff material.

It was standard practice during 1978 to clean the bags in House No. 2 manually or to put the baghouse in cleaning mode after episodes of high pressure drop across the house. Sometimes cleaning caused a reduction in pressure drop, sometimes not.

Two other filter media, Nomex felt and 15 oz./yd.^{2} woven glass, were tested in Baghouse No. 2 and found to be lacking in endurance for this particular application and set of operating conditions. It appears that the heavier weight woven glass fabric is more durable than the 15 oz./yd.^{2} fabric. The Nomex failed in less than ten (10) days.

The failure rate for the 26 oz./yd.^{2} woven glass bags was about 3% from August to December 1978, with the worst damage observed being small (1/8 in. diameter) holes.

Resistitivy tests were performed on both Teflon and woven glass bags in November 1978. Negligible voltage was observed on both types of filter bag, probably because of the conductivity of carbon in the ash deposits.

TABLE X

FILTER MEDIA CHARACTERISTICS

Filter Media	Weight Ozs./Yd.^{2}	Permeability CFM/Sq. Ft.	Mullen Burst psi	Tensile Strength Lb./Inc. Min.	Cost Per Bag (12/77)
Teflon(R) Felt Style 2663	21-29	15-45	250	180 X 150	$ 53
Gore-Tex(R) PTFE Laminate	4-5 +	8-15	239-400	-	45
Globe Albany(R) Woven Glass Type Q78-S1611	15	42	700	630 X 360	14.61
Globe Albany(R) Woven Glass Q78 Finish	22.5	25	800 +	-	18.65
Huyck - Experimental Needled Fabric	29 $\pm$ 2	40 $\pm$ 10	850	500 X 300	21.50*
P & S Woven Glass	26				
Nomex(R) Felt	14	25-35	450	131 X 100	-

* Based on Quote of $14.25/yd.^{2}

TABLE XI

BAG HISTORY

Baghouse No. 1

Date	No. of Bags Replaced	Comments
11/7/76	Start Up	100% Teflon Felt - Style 2663 (648 bags)
1/77		Removed 2 - suspected of leaking. Visual check and perm. showed OK
5/12/77		All bags manually vacuumed
7/77		All bags manually vacuumed
11/77		All bags manually vacuumed
1/78	3	Teflon bags removed for perm. tests Replaced w/new bags (front, mid. & back of house)
5/78		Pulse jet installed on 1 cell
5/78	13	Fluorescent dye - (only 1 had hole)
5/78		Teflon test by duPont - Table - bags props still good.
6/78	1	Teflon bag failed - shredded 3 ft. from bottom
7/78	50	Worn Teflon bags replaced Rebuilt multi-cyclone Installed pulse jet cleaning system Experimental Teflon felt (singed, sheared & napped) Installed 2 ea. in P.J. - 1 ea. in cell w.o. p.j.
8/78	1	Teflon bag failure - 1" hole at bottom
9/78	3	Bags removed & inspected - heavy pearling Orig. perm. not achievable w/vacuuming (Table)
11/78	3	Experiment Teflon bags retrieved, Inlet .46 gr/SCF

(continued)

TABLE XI (continued)

Date	No. of Bags Replaced	Comments
1/79		Test bags pulled
3/79	5	Defective Teflon bags replaced Perm results - Table
4/79		Decision to relocate/Data reduced - not given
11/28/79		Start up & shake-down operation of Unit No. 1
4/80		3 bags shredded, leak-lite test, most leaks small
7/80		Preliminary screening of light weight Teflon initiated.
8/80		Second set of light weight single-sided Teflon Felt installed for further study before final decision made on construction of 108 for test programs.
8/80	6	Leak light test performed and six (6) bags replaced small holes 1/8" dia. in all six.
9/80		Positive results on 2nd set of light weight Teflon Felt.
9/80		Fabric swatches and metal coupons installed.
10/80		Installed 108 light weight single-sided Teflon Felt in one section of house. House modified so that sub-division into 6 sections completed.
10/80		Leak light test performed and 27 bags leaking.
11/80		A number of Teflon bags removed for inspection and testing.
1/81		Interim report on single sided Teflon Felt.
2/81		3 light weight s.s. Teflon bags failed.

TABLE XI-A

BAG HISTORY

Baghouse No. 2

Date	No. of Bags Replaced	Comments
12/29/76	Start up	100% Gore-Tex PTFE Laminate on Woven Backing (648 bags)
3/28/77	36	Huyck felt placed in Cell 6A (from NTTC pilot plant)
4/77	8	4 Shrank (Forced Cage Up) Gore-Tex 4 Material Failure
		First Cleaning Was During May
5/77	25	Serious Damage During Cleaning (manual vacuuming)
5/22/77	36	22½ oz Globe Albany woven glass (Q78) placed in Cell 3A
7/77	30	Holes or tears apparently due to maintenance. Gore said bags should be steam-cleaned in place; can repair these
10/77	3	1 Shredded, 2 w/Small Holes (≈ 1" dia.)
11/77	14	Holes 1-1½" long in upper 2 feet of bag where contact rib of cage.
12/77		22½ oz G.A. bags inspected and found in satisfactory condition
2/21//8	36	Globe Albany 15 oz. woven glass (Q78) placed in Cell 5A
2/21/78	3	Nomex felt (calendered and singed) placed in Cells 1, 4 and 9 (study effect of singeing)
3/78	3	Nomex bags failed after 10 days on stream (holes)
3/78	2	Globe 15 oz. bags failed 1/2-3" holes near top
6/78	2	Globe 15 oz. bags failed 1/2-3" holes near top (total 4 of 36)
8/78	576	15 cells of Gore-Tex and one cell of 15 oz woven glass replaced w/26 oz. Woven Glass (10% Teflon B) 1 Cell Huyck & 1 cell orig. 22.5 oz.
9/78	36	Globe 22 1/2 oz. replaced w/26 oz. Woven Glass (P&S) (permeability tested)
9/78		Huyck bags inspected - no failures, appear OK, heavy cake
9/27/78		Rigid cages installed - Cell A-7

(continued)

TABLE XI-A (continued)

Date	No. of Bags Replaced	Comments
10/3/78		Tests on 26 oz. (new vs used), LOI 5%, strength loss 25-30% (ECC Report)
1/79		Test bags pulled. Fire at main Concord plant.
3/79	3	26 oz. bags leaking, ECC test 2 bags, no visible holes.
4/79		Decision to relocate
7/79		Glass bags removed for transport and vacuumed
1/29/80	216	#2 brought on line New woven glass bags (Carborundum, 14½oz.) and 216 galvanized mesh cages (Carborundum) installed (2 cells in each hopper A2, B2, A5, B5, A8, B8). Remainder of house contains relocated 26 oz. woven glass except Cell 6A contains Huyck Felt, all w/cages.
4/80		Bag check revealed substantial number of bag failures apparently related to cage support method. Very few failures have occurred in light weight glass using mesh cage support.
5/80		Wholesale bag failures. 26 oz. woven glass; inspection indicates 75-90% of bags have abraded holes in area of top 2-4 horizontal cage rings; believed due to cage moving vertically (unretained at top).
9/80		Fabric swatches and metal coupons installed
10/80		Removal of failed "26 oz." bags initiated
4/81		Installation of new bags of various types
5/81		Start up and conditioning of bags.

TABLE XII

PERMEABILITY TESTS

Month/Year	Filter Medium	Permeability, $ft^3/min/ft^2$ New	Dirty	Vacuumed
Feb. 1978	Globe Albany (GA) 15 oz/yd^2 woven glass	33		
March	Teflon felt		3.1	4.6
April	GA 15 oz/yd^2 woven glass		2.9	11
	GA 22.5 oz/yd^2 woven glass		3.2	5.3
	Teflon felt cleaned by pulse jet		1.9	4.6
	Teflon felt cleaned by reverse air		2.4	4.2
June	Teflon felt installed in May 1978		4.7	8.9
	Teflon felt installed in Nov. 1976		2.1	3.5
August	P+S Textiles heavy glass	20		
September	Teflon felt		3.9	4.1
	Woven glass		8.8	12
	Gore-Tex		3.0	3.1
November	Singed Teflon felt		3.2	10
	Sheared Teflon felt		4.6	8.8
	Napped Teflon felt		2.7	7.8
Feb. 1979	Teflon felt, bottom		8.3	21/Re-test: 13
	Teflon felt, top		8	29/Re-test: 13
	Teflon felt, side		10	46/Re-test: 22

D. APOLLO PROGRAM:

The Apollo test program consisted of the following two phases:

Phase I - Baseline studies

Phase II- Coaltrol Injection studies

During each phase of the study, both free acidity and total SO_x measurements were made. In order to measure the acid content at the most deleterious location, ash samples were taken from the bags. The ability of Coaltrol to reduce free acid was used as a measure of its effectiveness. SO_2 and SO_3 measurements were made in order to show the stability of the coal quality during the test program.

Indicators of the effectiveness of Coaltrol addition include reduced metal corrosion, reduced fabric deterioration and stable (possible lower) pressure drops across the bags. This program attempted to monitor the above during a relatively short time frame.

RESULTS:

Table XIII is a summary of the Unit I pressure drop data as a function of the average baghouse temperature. Figure R-4 is a plot of these data. The G/C ratio for all runs was 5.0 ($\pm$ 10%) and was maintained by introduction of fresh air upstream of the Coaltrol feed point. The temperature of the baghouse was controlled by the preheat temperature of the reverse air to the unit. The average temperature ranged from about 10°F below the inlet temperature at 200°F to about 30°F below the inlet at 400°F.

Although the scatter of the data is quite great, a tentative correlation of the 29 available data points is shown on the graph.

This temperature effect on pressure drop is due to the shrinkage of the

Teflon felt bags with elevation of temperature. Laboratory measurements of the Teflon felt permeability (perm) as a function of temperature by ETS, confirmed by duPont, corroborate that the perm of the Teflon felt material used in Unit I does indeed decrease as temperature increases, because of fabric shrinkage. The perm decrease with temperature increase results in a higher pressure drop for a given G/C ratio. Therefore, it is economically advantageous, when Teflon felt is used, to operate at lower temperatures. The addition of Coaltrol to reduce the acid dewpoint makes such low temperature operation possible because the Coaltrol reduced the SO_3 concentration to the point where, even at 200°F, the baghouse temperature is still above the acid dew point.

The SO_3 and free acidity data are summarized in Table XIV. In all cases, the free acidity of the bag sample dust, reported as mg H_2SO_4 per g ash, was very significantly reduced by Coaltrol addition.

Two data points - for addition of 1.0 and 1.6 lb. of Coaltrol per hour - indicate SO_3 concentrations entering the baghouse below detectable amounts (reported as 0 ppm). However, analyses of the effluent gases during addition of 1.2 and 1.6 lb. per hr. of Coaltrol indicate 2.4 and 3.1 ppm of SO_3. If the Coaltrol reduced the SO_3 in the inlet gases to 0 ppm, the presence of SO_3 in the effluent gases must have been due to oxidation of SO_2 to SO_3 in the baghouse itself.

EFFECTS OF COALTROL ADDITION ON SWATCH PROPERTIES:

Table XV is a summary of data for swatches of nylon (Nomex), fiberglass (2 kinds), acrylics (Dratex and Badische), and a dacron (Terytex). The swatches were hung in the baghouses ONLY during the Coaltrol addition tests,

a total of 207 hours.

(i.) Nylon

The burst strength of the Nomex was not significantly affected by Coaltrol addition, but the permeabilities of the swatches in Unit 1 (Coaltrol added) seem to have been reduced more than the permeability of the swatches in Unit 2 (no Coaltrol). There is no difference between the permeabilities of the vacuumed swatches.

(ii.) Fiberglass

The permeabilities of the samples of FBG0960 in both Units 1 and 2 were extremely low, 3 FPM, after aging. The permeability recovery of the swatches in Unit 2 (no Coaltrol) on vacuuming was much greater. The Mullen burst strength of the Unit 2 swatches was significantly reduced, as compared to the Unit 1 swatches.

The samples of AMF BG/29 show no apparent differences between the Unit 1 and Unit 2 swatches in either perm or burst strength.

(iii.) Acrylics

Both the Dratex and Badische swatches in the Unit 2 baghouse were too brittle to test for perm, and the size of the swatches recovered were too small to burst test. The Unit 1 swatches could be tested but, on vacuuming, showed significant loss of perm and burst strength.

(iv.) Dacron

The Terytex Dacron samples all showed greatly reduced burst strength. Vacuumed perms were equivalent to new sample perms.

Based on SWATCH TEST RESULTS, it can be concluded that in the case of Dratex and also Woven Fiberglass (FBG0960), the Coaltrol addition favorably affected the strength properties. In no case was an adverse effect of the

Coaltrol addition apparent.

EFFECTS OF COALTROL ADDITION ON METAL CORROSION:

Table XVI summarizes the data on weight loss of carbon steel and 316 stainless steel metal coupons which were hung in Units 1 and 2 during the Coaltrol addition tests for a total residence time of 207 hours. (Coupons were removed when Coaltrol was not being added.)

Although the data are very meager, in both cases, the metal weight loss was less when the atmosphere was treated with Coaltrol.

TABLE XIII

EFFECT OF AVERAGE UNIT I TEMPERATURE ON BAGHOUSE PRESSURE DROP

G/C Ratio 5.0 $\pm$ .5

Avg. Unit I Temp. ^{o}F	Pressure Drop, Inches of Water
190	10.5 (3 pts.)
200	10.0
215	6.5
215	10.5
225	8.5 (2 pts.)
225	10.0
230	10.0
230	10.5
235	8.0 (2 pts.)
235	9.0 (2 pts.)
235	9.5
235	10.0 (2 pts.)
240	9.0 (2 pts.)
260	6.0
315	9.5
325	10.5
335	11.5 (2 pts.)
340	10.5
350	12.0
355	9.5 (2 pts.)

Figure R-4

Effect of Temperature on Unit 1 Baghouse Pressure Drop

G/C Ratio 5.0 $\pm$ .5

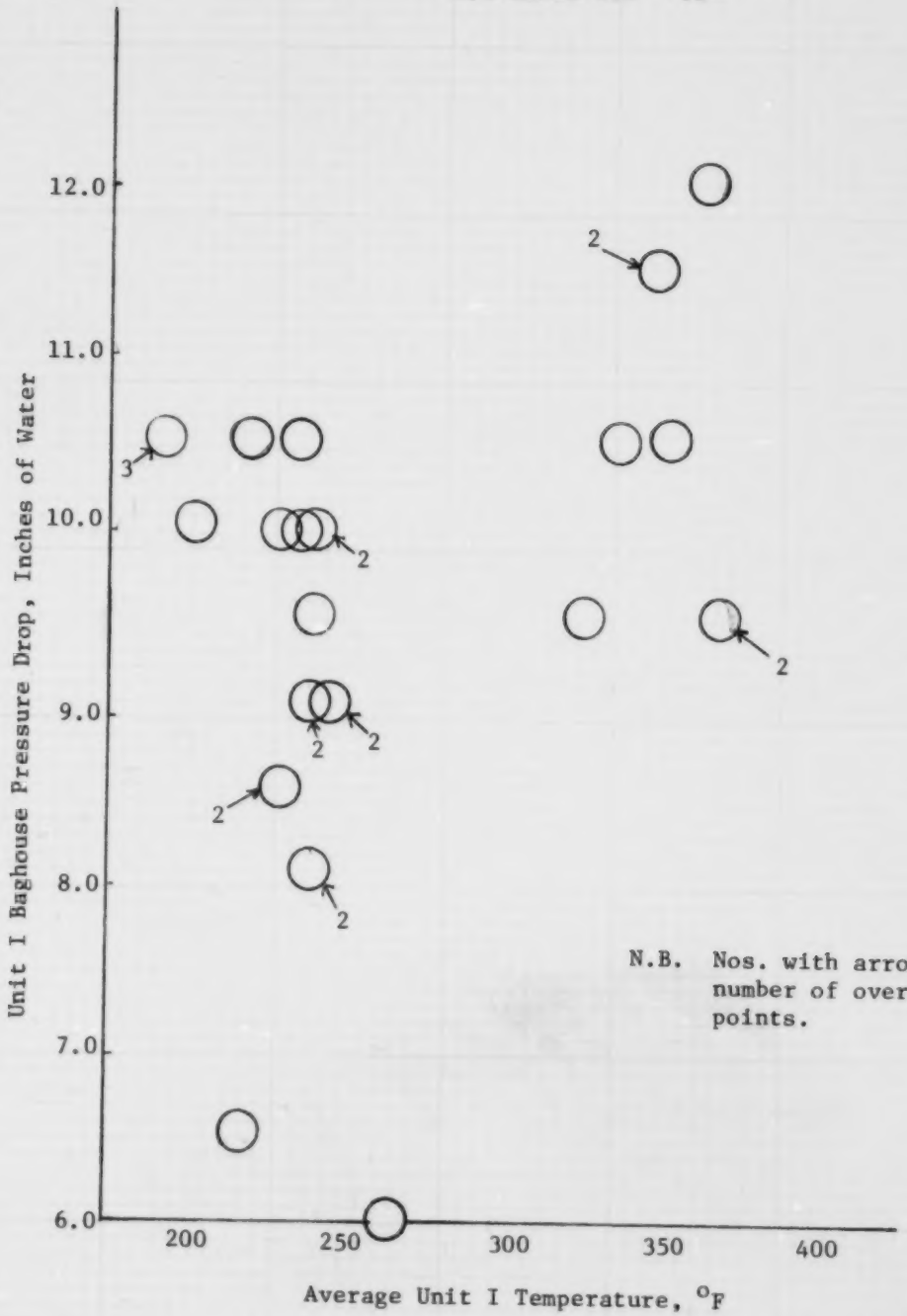


TABLE XIV

EFFECT OF COALTROL X ADDITION ON SO_x AND FREE ACIDITY

Coaltrol Rate, lb/hr.	SO_3, PPM		SO_2, PPM		Free Acidity mg HSO_4 per g ash		
	Inlet[d]	Outlet	Inlet[d]	Outlet	Inlet	Outlet	Bag Sample
0	3.1[a]	3.1[a]	440[b]	330[c]	1.6[e]	1.6[e]	4.5 ± 1.1[g]
0.9	-	-	-	-	-	1.0	0.3
1.0	0	-	370	-	-	-	-
1.2	-	2.4	-	450	-	-	0.2
1.3	-	-	-	-	0.7	-	0.2
1.6	0	3.1	240	560[f]	0.5	-	0.0
4.0	-	0	-	220	0.0	-	-
5.3	-	-	-	-	-	0.4	0.2
10.0	-	-	-	-	-	-	0.0

"Dash" indicates no data taken under these conditions.

a. average of 18 values.
b. average of 11 values.
c. average of 7 values.
d. Coaltrol injection was upstream of SO_x sample pt.
e. average of 18 values.
f. This point appears to be badly in error.
g. Average of 32 values, $\pm$ 95% confidence limit on the average. (Std. dev. for these values was 3.09.)

TABLE XV

EFFECT OF COALTROL X ADDITION ON FILTER MEDIA SWATCHES

(Residence Time: 207 hours)

Material	Baghouse *	Permeability, FPM			Mullen Burst Strength, PSI	
		New	As Rec'd	Vacuumed Clean (b)	New	Used
Nylon (Nomex)					460	
24	#1	34	3	21		560
25	1	35	13	29		410
26	1	40	15	28		520
27	1	35	9	27		500
28	#2	35	22	18		480
29	2	33	22	26		420
Woven Fiberglass (FBG0960)					280	
36	#1	48	3	28		350
37		48	3	30		340
34	#2	51	3	57		(c)
35		54	3	53		190
Fiberglass (AMFBG/29)					710	
30	#1	31	13	29		840
31		36	5	32		790
32	#2	32	18	33		1000
33		33	10	29		770
Acrylic (DRATEX; AMD11530)					260	
44	#1	51	16	23		55
45	1	54	14	22		50
46	1	59	6	18		65
47	1	53	4	21		45
42	#2	59	(a)	-		(c)
43	2	55	(a)	-		(c)
Dracron (TeryTex; AMT31630SST)					420	
40	#1	44	16	45		<10
41	1	36	11	35		<10
38	#2	38	(a)	38		<10
39	2	34	19	28		<10
Acrylic, Woven (Badische)					290	
48	#1	7.7	1.0	1.5		45
51	1	7.6	1.2	1.4		50
52	1	7.4	1.3	1.2		35
53	1	7.2	1.4	1.8		25
49	#2	7.3	(a)	-		(c)
50	2	7.4	(a)	-		(c)

(continued)

TABLE XV (continued)

Note: (a) Sample too brittle to test.

(b) 30 inches W.G.

(c) Sample too small to test.

Material	Sample Wt., Oz./Yd.^{2}
Nomex	14
DraTex	16
TeryTex	16
AMFBG/29	29
FBG0960	9.2
Badische	-

* Baghouse #1 - had Coaltrol addition.

Baghouse #2 - had no Coaltrol addition.

TABLE XVI

EFFECT OF COALTROL ADDITION OF METAL CORROSION

(Residence time: 207 hours)

% Weight Loss of metal coupon

Metal	Unit 1 (Coaltrol)	Unit 2 (No Coaltrol)
Carbon Steel	0.00	0.57
	0.02	
Stainless Steel	0.00	0.46
	0.08	
	0.23	

VIII. ECONOMICS

In order to better direct the development program, an economic study of the impact of various costs was undertaken. Key parameters evaluated included bag cost, pressure drop cost and gas-to-cloth ratio. Unlike the earlier economic evaluations of Kerr where specific bag cost and/or measured pressure drops were utilized, the current study has been done in a generalized manner so that the cost benefit of achieving a yet untested operating mode could be evaluated.

The approach was specific to Kerr in that a fixed gas volume of 70,000 ACFM was employed. However, the results obtained here will provide some general economic insights valid for half this volume to twice this amount, thus suitable for many industrial boiler applications. The main variables studied and the range covered for each is shown in Table E-1.

Pressure Drop

Table E-2 shows that if the gas-to-cloth is held constant (4.7/1) each inch of pressure drop increases costs an additional $1700/year in operating cost and annualized cost. At the 6 in. pressure drop level, this is more than 10% of the operating cost for a $10 bag and about 7% for a $30 bag. In terms of annualized cost, each inch of pressure drop costs an additional $1700/year which is only about 1% of the total annualized costs.

Bag Replacement

Bag life of 1, 2, 3 and 4 years was evaluated and this cost analysis is shown in Tables E-3, E-4 and E-5. For the case of a $50 bag and a pressure drop of 6 inches, a four year bag life (25% replacement per year) results in

an annualized cost of $170,837 (see Table E-3). In the case of a $20 bag and the same pressure drop, this cost is matched with slightly more than one year bag life (see Table E-4) and in the case of a $30 bag, a two year bag life achieves this cost (see Table E-5). This comparison shows how significant bag cost is on annualized cost and the merit of seeking out lower cost bags.

Taking the case of three year bag life and 6 inch pressure drop, it's seen that an increase in bag cost from $10 to $20 results in a 30% increase in operating cost and a 4% increase in annualized cost. (see Table E-2).

Interest Rates

While interest rates are not a controllable parameter, its impact was investigated in light of the dramatic fluctuations experienced in recent times. Table E-6 shows that in the range studied, a five percent increase in interest rates results in approximately 20% increase in annualized costs.

Gas-to-Cloth Ratio

The reduction in annualized cost resulting from an increase in gas-to-cloth ratio is shown in Figure E-1 developed from Tables E-3, E-7 and E-8. The G/C range studied was 2 to 10. A family of curves is provided. Each curve representing a different bag life for the case of 3 year bag life, $50 bag cost and 6 in. pressure drop. An increase in G/C from 4.7 to 9.4 results in the annualized cost being reduced from $155,993 to $103,157. Thus, for the case studied each 1 ft./min. increase in G/C results in approximately a 7% decrease in annualized costs.

This analysis indicates the relative merits of striving for changes in operating conditions. For example, it indicates that if an increase in G/C

of 1 ft./min. can be achieved at the expense of increasing pressure drop one inch it has economic merit. A brief summary of the results is given in Table E-9. While this analysis is very useful in directing the program towards the operating conditions with the greatest economic merit, it must be recognized that the results are for specific cases studied and attempts to generalize beyond these cases can be misleading. In order to relate this general analysis to the specific bags tested in this program, actual bag costs are provided in Table E-10. The specific flange-to-flange components employed in the cost analysis are given in Table E-11. The updated flange-to-flange cost corresponding to the case with a G/C of 4.7 is given in Table E-12. Table E-13 provides a list of equipment included in the installed cost.

The methodology for calculating the various costs is given in the appendix.

FIGURE E-1

ANNUALIZE COST - $/ACFM VS. G/C AT VARIOUS BAG REPLACEMENTS

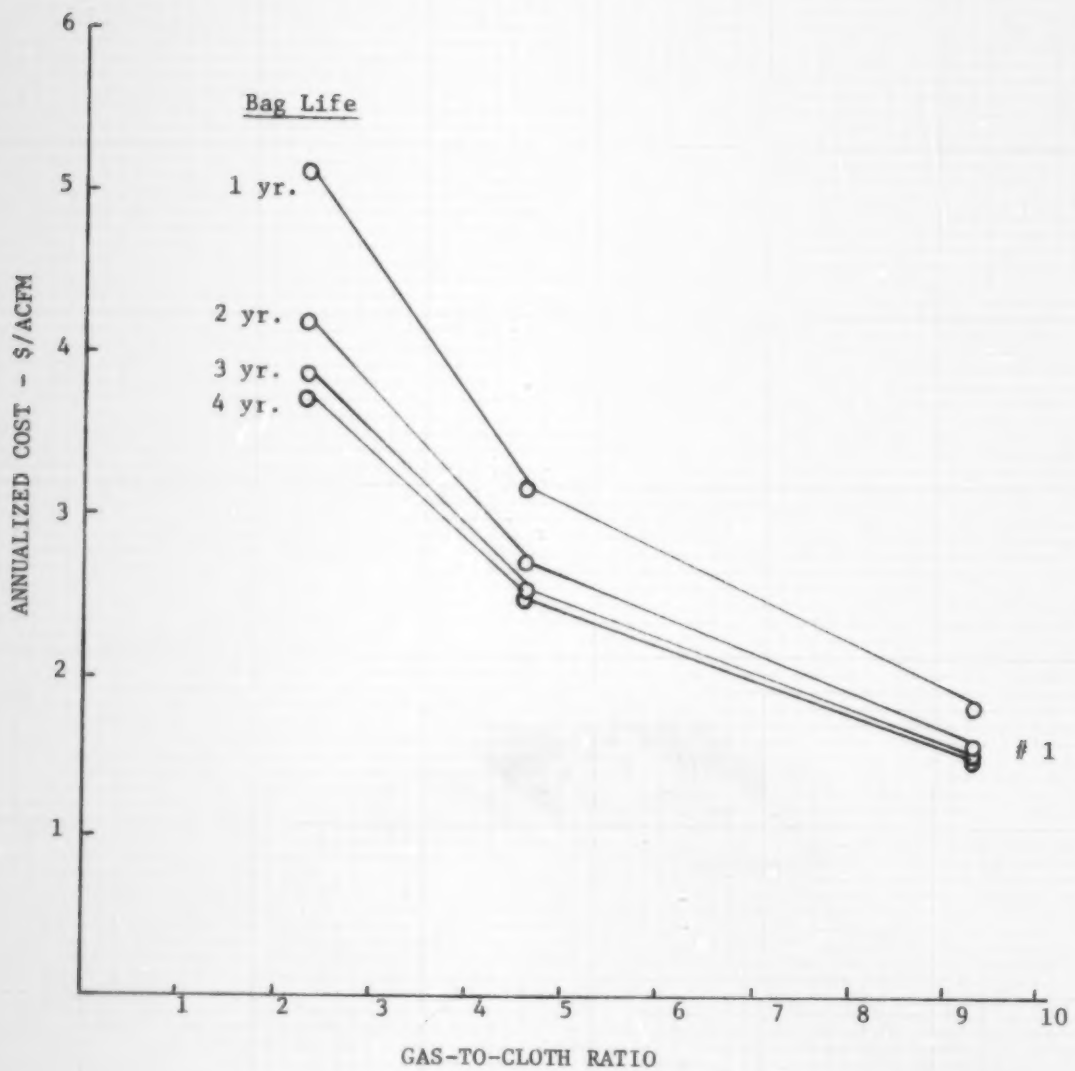


TABLE E-1

VARIABLES STUDIED IN ECONOMIC EVALUATION

VARIABLE	RANGE
Pressure Drop	3 to 15 in. water
Bag Costs	$10 to $100
Interest	5% to 20%
Bag Replacement	25 to 100%/yr.
Gas-to-cloth Ratio	2 to 10

TABLE E-2

INSTALLED, OPERATING AND ANNUALIZED COSTS AS A FUNCTION OF BAG COST

BAG COST	PRESSURE DROP IN. H_2O	INSTALLED COST - $	INSTALLED COST - $/ACFM	OPERATING COST - $	OPERATING COST - $/ACFM	ANNUALIZED COST - $	ANNUALIZED COST - $/ACFM
10	3	721,666	10.31	9,401	0.13	144,112	2.06
	6	"	"	14,526	0.21	149,237	2.13
	9	↓	↓	19,651	0.28	154,362	2.21
	12			24,775	0.35	159,486	2.28
	15			29,900	0.43	164,611	2.35
	18			35,025	0.50	169,736	2.42
20	3	734,626	10.49	13,678	0.20	150,808	2.15
	6	"	"	18,803	0.27	155,933	2.23
	9	↓	↓	23,928	0.34	161,058	2.30
	12			29,052	0.42	166,182	2.37
	15			34,177	0.49	171,307	2.45
	18			39,301	0.56	176,432	2.52
30	3	747,586	10.68	17,955	0.26	157,504	2.25
	6	"	"	23,080	0.33	162,629	2.32
	9	↓	↓	28,204	0.40	167,754	2.40
	12			33,329	0.48	172,878	2.47
	15			38,454	0.55	178,003	2.54
	18			43,578	0.62	183,128	2.62
50	3	773,506	11.05	26,509	0.38	170,896	2.44
	6	"	"	31,633	0.45	176,021	2.51
	9	↓	↓	36,758	0.53	181,146	2.59
	12			41,883	0.60	186,270	2.66
	15			47,007	0.67	191,395	2.73
	18			52,132	0.74	196,520	2.81
100	3	838,306	11.98	47,893	0.68	204,376	2.92
	6	"	"	53,017	0.76	209,501	2.99
	9	↓	↓	58,142	0.83	214,626	3.07
	12			63,267	0.90	219,750	3.14
	15			68,391	0.98	224,875	3.21
	18			73,516	1.05	230,000	3.29

CASE: FAN EFFICIENCY .6 POWER $.02 NO. OF BAGS 1,296 CAPITAL COST .12
HOURS IN USE 6,240 BAG REPLACE/YR 33 GAS-TO-CLOTH RATIO 4.7
GAS VOLUME 70,000 FLANGE/FLANGE COST $ 416,886 DEPRECIATION 15 YRS.

TABLE E-3

OPERATING AND ANNUALIZED COSTS AS A FUNCTION OF % BAG REPLACE/YR

%BAG REPLA/YR	PRESSURE DROP IN.H20	OPERATING COST-$	OPERATING COST-$/ACFM	ANNUALIZED COSTS:$	ANNUALIZED COST-$/ACFM
25	3	21325	0.30	165712	2.37
	6	26449	0.38	170837	2.44
	9	31574	0.45	175962	2.51
	12	36699	0.52	181086	2.59
	15	41823	0.60	186211	2.66
	18	46948	0.67	191336	2.73
33	3	26509	0.38	170896	2.44
	6	31633	0.45	176021	2.51
	9	36758	0.53	181146	2.59
	12	41883	0.60	186270	2.66
	15	47007	0.67	191395	2.73
	18	52132	0.74	196520	2.81
50	3	37525	0.54	181912	2.60
	6	42649	0.61	187037	2.67
	9	47774	0.68	192162	2.75
	12	52899	0.76	197286	2.82
	15	58023	0.83	202411	2.89
	18	63148	0.90	207536	2.96
100	3	69925	1.00	214312	3.06
	6	75049	1.07	219437	3.13
	9	80174	1.15	224562	3.21
	12	85299	1.22	229686	3.28
	15	90423	1.29	234811	3.35
	18	95548	1.36	239936	3.43

CASE: FAN EFFICIENCY .6 POWER $ .02 NO. OF BAGS 1296 CAPITAL COST .12
HOURS IN USE 6240 BAG COST $ 50 GAS-TO-CLOTH RATIO 4.7 INSTALLED COST $773506
GAS VOLUME 70000 FLANGE/FLANGE COST $ 416886 DEPRECIATION 15 YRS. INSTALLED COST $11.05/ACFM

TABLE E-4

OPERATING AND ANNUALIZED COSTS AS A FUNCTION OF % BAG REPLACE/YR

%BAG REPLA/YR	PRESSURE DROP IN.H20	OPERATING COST-$	OPERATING COST-$/ACFM	ANNUALIZED COSTS:$	ANNUALIZED COST-$/ACFM
25	3	11605	0.17	148735	2.12
	6	16729	0.24	153860	2.20
	9	21854	0.31	158984	2.27
	12	26979	0.39	164109	2.34
	15	32103	0.46	169233	2.42
	18	37228	0.53	174358	2.49
33	3	13678	0.20	150808	2.15
	6	18803	0.27	155933	2.23
	9	23928	0.34	161058	2.30
	12	29052	0.42	166182	2.37
	15	34177	0.49	171307	2.45
	18	39301	0.56	176432	2.52
50	3	18085	0.26	155215	2.22
	6	23209	0.33	160340	2.29
	9	28334	0.40	165464	2.36
	12	33459	0.48	170589	2.44
	15	38583	0.55	175713	2.51
	18	43708	0.62	180838	2.58
100	3	31045	0.44	168175	2.40
	6	36169	0.52	173300	2.48
	9	41294	0.59	178424	2.55
	12	46419	0.66	183549	2.62
	15	51543	0.74	188673	2.70
	18	56668	0.81	193798	2.77

CASE: FAN EFFICIENCY .6 POWER $ .02 NO. OF BAGS 1296 CAPITAL COST .12
HOURS IN USE 6240 BAG COST $ 20 GAS-TO-CLOTH RATIO 4.7 INSTALLED COST $734626
GAS VOLUME 70000 FLANGE/FLANGE COST $ 416886 DEPRECIATION 15 YRS. INSTALLED COST $10.49/ACFM

TABLE E-5

OPERATING AND ANNUALIZED COSTS AS A FUNCTION OF % BAG REPLACE/YR

%BAG REPLA/YR	PRESSURE DROP IN.H20	OPERATING COST-$	OPERATING COST-$/ACFM	ANNUALIZED COSTS:$	ANNUALIZED COST-$/ACFM
25	3	14845	0.21	154394	2.21
	6	19969	0.29	159519	2.28
	9	25094	0.36	164643	2.35
	12	30219	0.43	169768	2.43
	15	35343	0.50	174893	2.50
	18	40468	0.58	180017	2.57
33	3	17955	0.26	157504	2.25
	6	23080	0.33	162629	2.32
	9	28204	0.40	167754	2.40
	12	33329	0.48	172878	2.47
	15	38454	0.55	178003	2.54
	18	43578	0.62	183128	2.62
50	3	24565	0.35	164114	2.34
	6	29689	0.42	169239	2.42
	9	34814	0.50	174363	2.49
	12	39939	0.57	179488	2.56
	15	45063	0.64	184613	2.64
	18	50188	0.72	189737	2.71
100	3	44005	0.63	183554	2.62
	6	49129	0.70	188679	2.70
	9	54254	0.78	193803	2.77
	12	59379	0.85	198928	2.84
	15	64503	0.92	204053	2.92
	18	69628	0.99	209177	2.99

CASE: FAN EFFICIENCY .6 POWER $ .02 NO. OF BAGS 1296 CAPITAL COST .12
HOURS IN USE 6240 BAG COST $ 30 GAS-TO-CLOTH RATIO 4.7 INSTALLED COST $747586
GAS VOLUME 70000 FLANGE/FLANGE COST $ 416886 DEPRECIATION 15 YRS. INSTALLED COST $10.68/ACFM

TABLE E-6

ANNUALIZED COSTS AS A FUNCTION OF CAPITAL COST RATE

CAP.COST RATE	PRESSURE DROP IN.H20	OPERATING COST-$	OPERATING COST-$/ACFM	ANNUALIZED COST-$	ANNUALIZED COST-$/ACFM
.07	3	26509	0.38	132221	1.89
	6	31633	0.45	137346	1.96
	9	36758	0.53	142470	2.04
	12	41883	0.60	147595	2.11
	15	47007	0.67	152720	2.18
	18	52132	0.74	157844	2.25
.12	3	26509	0.38	170896	2.44
	6	31633	0.45	176021	2.51
	9	36758	0.53	181146	2.59
	12	41883	0.60	186270	2.66
	15	47007	0.67	191395	2.73
	18	52132	0.74	196520	2.81
.17	3	26509	0.38	209572	2.99
	6	31633	0.45	214696	3.07
	9	36758	0.53	219821	3.14
	12	41883	0.60	224946	3.21
	15	47007	0.67	230070	3.29
	18	52132	0.74	235195	3.36
.22	3	26509	0.38	248247	3.55
	6	31633	0.45	253372	3.62
	9	36758	0.53	258496	3.69
	12	41883	0.60	263621	3.77
	15	47007	0.67	268746	3.84
	18	52132	0.74	273870	3.91

CASE: FAN EFFICIENCY .6 POWER $ .02 NO. OF BAGS 1296 BAG REPLACE RATE 33 %/YR
HOURS IN USE 6240 BAG COST $ 50 GAS-TO-CLOTH RATIO 4.7 INSTALLED COST $773506
GAS VOLUME 70000 FLANGE/FLANGE COST $ 416886 DEPRECIATION 15 YRS. INSTALLED COST $11.05/ACFM

TABLE E-7

OPERATING AND ANNUALIZED COSTS AS A FUNCTION OF % BAG REPLACE/YR

%BAG REPLA/YR	PRESSURE DROP IN.H20	OPERATING COST-$	OPERATING COST-$/ACFM	ANNUALIZED COSTS:$	ANNUALIZED COST-$/ACFM
25	3	13225	0.19	95441	1.36
	6	18349	0.26	100565	1.44
	9	23474	0.34	105690	1.51
	12	28599	0.41	110814	1.58
	15	33723	0.48	115939	1.66
	18	38848	0.55	121064	1.73
33	3	15817	0.23	98033	1.40
	6	20941	0.30	103157	1.47
	9	26066	0.37	108282	1.55
	12	31191	0.45	113406	1.62
	15	36315	0.52	118531	1.69
	18	41440	0.59	123656	1.77
50	3	21325	0.30	103541	1.48
	6	26449	0.38	108665	1.55
	9	31574	0.45	113790	1.63
	12	36699	0.52	118914	1.70
	15	41823	0.60	124039	1.77
	18	46948	0.67	129164	1.85
100	3	37525	0.54	119741	1.71
	6	42649	0.61	124865	1.78
	9	47774	0.68	129990	1.86
	12	52899	0.76	135114	1.93
	15	58023	0.83	140239	2.00
	18	63148	0.90	145364	2.08

CASE: FAN EFFICIENCY .6 POWER $ .02 NO. OF BAGS 648 CAPITAL COST .12
HOURS IN USE 6240 BAG COST $ 50 GAS-TO-CLOTH RATIO 9.4 INSTALLED COST $440443
GAS VOLUME 70000 FLANGE/FLANGE COST $ 240025 DEPRECIATION 15 YRS. INSTALLED COST $6.29/ACFM

TABLE E-8

OPERATING AND ANNUALIZED COSTS AS A FUNCTION OF % BAG REPLACE/YR

%BAG REPLA/YR	PRESSURE DROP IN.H20	OPERATING COST-$	OPERATING COST-$/ACFM	ANNUALIZED COSTS:$	ANNUALIZED COST-$/ACFM
25	3	37525	0.54	253989	3.63
	6	42649	0.61	259114	3.70
	9	47774	0.68	264238	3.77
	12	52899	0.76	269363	3.85
	15	58023	0.83	274487	3.92
	18	63148	0.90	279612	3.99
33	3	47893	0.68	264357	3.78
	6	53017	0.76	269482	3.85
	9	58142	0.83	274606	3.92
	12	63267	0.90	279731	4.00
	15	68391	0.98	284855	4.07
	18	73516	1.05	289980	4.14
50	3	69925	1.00	286389	4.09
	6	75049	1.07	291514	4.16
	9	80174	1.15	296638	4.24
	12	85299	1.22	301763	4.31
	15	90423	1.29	306887	4.38
	18	95548	1.36	312012	4.46
100	3	134725	1.92	351189	5.02
	6	139849	2.00	356314	5.09
	9	144974	2.07	361438	5.16
	12	150099	2.14	366563	5.24
	15	155223	2.22	371687	5.31
	18	160348	2.29	376812	5.38

CASE: FAN EFFICIENCY .6 POWER $ .02 NO. OF BAGS 2592 CAPITAL COST .12
HOURS IN USE 6240 BAG COST $ 50 GAS-TO-CLOTH RATIO 2.4 INSTALLED COST $115963
GAS VOLUME 70000 FLANGE/FLANGE COST $ 605900 DEPRECIATION 15 YRS. INSTALLED COST $16.57/ACFM

TABLE E-9

COST - SUMMARY OF RESULTS

VARIABLE	INCREMENT	ANNUALIZED COST REDUCTION
Interest Rate	5%	20%
Gas-To-Cloth Ratio	1 ft./min.	7%
Bag Life	1 yr.	6%
Bag Cost *	$ 10	4%
Pressure Drop	1 in.	1%

Case Considered
All:
Power cost .02
Fan eff. .6
Volume 70,000
15-yr. depreciation

Where applicable:

ΔP = 6 in.
Bag Life = 3 yr.
Cap. Cost = .12
Bag Costs = $ 50

* Basis: 5 in. dia. X 8 ft. 8 in. length bag dimensions

TABLE E-10

APPROXIMATE BAG COSTS *

MATERIAL	WEIGHT (OZ.)	PRICE/BAG ($)
Woven Glass	10	20
Woven Glass	16	23
Felted Glass	27	42
Teflon Felt	23	110

* Prices are based upon a nominal 5-inch diameter, 8 feet - 8 inch long bag.

TABLE E-11

List of Components Included in the Flange-to-Flange Collector Costs

(Coal-Fired Boiler Applications)

Collector
Supports
Timer
Pulse Assist Cleaning System
High Pressure Switch
High Temperature Switch
Double Dump Valves
Heater
Ladder
Paint
Insulation (2 Inches Thick)

TABLE E-12

BILL OF MATERIALS

Job No. 76-100 *

Item	Qty.	Part No.	Material	Actual Costs
1	2	S-9101P9	648-RAC3-5-104 Baghouse with Insulation & Struct & Pulse Assist Clean Sys.	$ 162,900
2	1296	S-2096	Rigid Case Assemblies (Included in 1)	--
3	1		Compressor System	9,200
4	2	S-9102P9	9 Module Pyramid Hoppers With Insulation (Included in 1)	--
5	1 Lot	76-100-	Walkways	11,000
6	1	76-100-	Pent House Assembly	19,700
7	1	76-100-	System Motor Control Center	52,216
8	1 Lot	76-100-	Ductwork With Relief Caps and Dampers	74,173
9	1	76-100-	Control House	45,595
10	2	76-100-	System Fan Assemblies	33,102
11	6	S-9144	Double Dump Valves	9,000
12	1	76-100-	Motor Speed Control Center (Included in 7)	--
13	1	76-100-	System Control Console (Included in 7)	--
14	1		Heat Control System (Included in 7)	--
			TOTAL	$ 416,886

* Updated prices 1981

TABLE E-13

List of Equipment Included in "Installed Cost"

COLLECTOR

Standard Collector Components
Bags

COLLECTOR AUXILIARY COMPONENTS

Support Structure
Cleaning Control Panel (Standard)
Pulse Assist Cleaning System
High-Pressure Switch
High-Temperature Switch
Double Dump Valves
Handrails
Ladder
Paint
Insulation

SYSTEM AUXILIARIES

Control Panel
Cross Screw
Ductwork
System Fan
Relief Cap
Installation

ENGINEERING SERVICES

Site Survey
Design & Engineering
Drawings
Start-Up and Instruct

APPENDIX

Units of Measure - Conversions

Glossary of Terms

References

Cost Calculations

UNITS OF MEASURE - CONVERSIONS

Environmental Protection Agency policy is to express all measurements in Agency documents in metric units. When implementing this practice will result in undue costs or lack of clarity, conversion factors are provided for the non-metric units used in a report. Generally, this report uses British units of measure. For conversion to the metric system, use the following conversions:

TO CONVERT FROM	TO	MULTIPLY BY
^{o}F	^{o}C	$\frac{5}{9}$ (^{o}F-32)
ft.	meters	0.304
$ft.^2$	$meters^2$	0.0929
$ft.^3$	$meters^3$	0.0283
ft/min (fpm)	centimeters/sec	0.508
$ft.^3$/min	$centimeters^3$/sec	471.9
in	centimeters	2.54
in^2	$centimeters^2$	6.45
oz	grams	28.34
oz/yd^2	$grams/meter^2$	33.89
grains	grams	0.0647
$grains/ft^3$	$grams/meter^3$	2.288
lb force	dynes	4.44×10^5
lb mass	kilograms	0.453
lb/ft^2	$grams/centimeter^2$	0.488
in H_2O/ft/min	cm H_2O/cm/sec	5.00
$\frac{\text{in } H_2O/\text{ft/min}}{lb/ft^2}$	$\frac{\text{cm } H_2O/\text{cm/sec}}{gr/cm^2}$	10.24

GLOSSARY OF TERMS

ACID DEW-POINT - The temperature at which the condensation of the acid vapors initiates for a given state of humidity and pressure.

AIR-TO-CLOTH RATIO - The volumetric rate of capacity of a fabric filter; the volume of air (gas), cubic feet per minute, per square foot of filter media (fabric).*

BAG - The customary form of filter element. Also known as tube, stocking, etc. Can be unsupported (dust on onside) or used on the outside of a grid support (dust on the outside).

BLINDING (BLINDED) - The loading, or accumulation, of filter cake to the point where capacity rate is diminished. Also termed "plugged".

CLOTH - In general, a pliant fabric; - woven, knitted, felted, or otherwise formed of any textile fiber, wire, or other suitable material.

CLOTH WEIGHT - Is usually expressed in ounces per square yard or ounces per square foot. However, cotton sateen is often specified at a certain number of linear yards per pound of designated width. For example, a 54" - 1.05 sateen measures 1.05 linear yards per pound in a 54" width.

DAMPER - An adjustable plate installed in a duct for the purpose of regulating air flow.

DIMENSIONAL STABILITY - Ability of the fabric to retain finished length and width, under stress, in hot or moist atmosphere.

DUST LOADING - The weight of solid particulate suspended in an air (gas) stream, usually expressed in terms of grains per cubic foot, grams per cubic meter or pounds per thousand pounds of gas.

* Although it is EPA's policy to use the metric system for quantitative descriptions, the British system is used in this report because not to do so would tend to confuse some readers from industry. Readers who are more accustomed to metric units may use the table of conversions in the appendix to facilitate the translation.

GLOSSARY OF TERMS

FABRIC - A planar structure produced by interlacing yarns, fibers or filaments.

KNITTED fabrics are produced by interlooping strands of yarn, etc.

WOVEN fabrics are produced by interlacing strands at more or less right angles.

BONDED fabrics are structures built up by the interlocking action of the fibers themselves, without spinning, weaving or knitting.

FELTED fabrics are structures built up by the interlocking action of the fibers themselves, without spinning, weaving or knitting.

FILTER MEDIA - The substrate support for the filter cake; the fabric upon which the filter cake is built.

FILTER VELOCITY - The velocity, feet per minute, at which the air (gas) passes through the filter media, or rather the velocity of approach to the media. The filter capacity rate.

FILTRATION RATE - The volume of air (gas), cubic feet per minute, passing through one square foot of filter media.

FRACTIONAL EFFICIENCY - The determination of collection efficiency for any specific size or size range of particles.

GRAIN - 1/7000 pound or approximately 65 milligrams.

INCH OF WATER - A unit of pressure equal to the pressure exerted by a column of liquid water one inch high at a standard temperature. The standard temperature is ordinarily taken as 70^{o}F. One inch of water at 70^{o}F. = 5.196 lb per sq. ft.

MASS MEAN PARTICLE DIAMETER - Refers to the point of a curve plotting particle diameter versus cumulative mass percent that shows 50% of the material is less than and 50% of the material is greater than the indicated particle diameter.

MICRON (μm) -A unit of length, the thousandth part of 1 mm or the millionth of a meter, (approximately 1/25,000 of an inch).

MULLEN BURST - The pressure necessary to rupture a secured fabric specimen, usually expressed in pounds per square inch.

GLOSSARY OF TERMS

NEDDLED FELT - A felt made by the placement of loose fiber in a systematic alignment, with barbed needles moving up and down, pushing and pulling the fibers to form an interlocking of adjacent fibers.

NON-WOVEN FELT - A felt made either by needling, matting of fibers or compressing with a bonding agent for permanency.

NYLON - A manufactured fiber in which the fiber forming substance is any long-chain synthetic polyamide having recurring amide groups.

PEARLING - Refers to a condition of the dust cake on the fabric which appears as nodular structures of agglomerated dust.

PERMEABILITY, FABRIC - Measured on Frazier porosity meter, or Gurley permeometer, etc. Not to be confused with dust permeability. The ability of air (gas) to pass through the fabric, expressed in cubic feet of air per minute per square foot of fabric with a 0.5" H_2O pressure differential.

PITOT TUBE - A means of measuring velocity pressure. A device consisting of two tubes - one serving to measure the total or impact pressure existing in an air stream, the other to measure the static pressure only. When both tubes are connected across a differential pressure measuring device, the static pressure is compensated automatically and the velocity pressure only is registered.

POROSITY, FABRIC - Term often used interchangeably with permeability. Actually percentage of voids per unit volume - therefore, the term is improperly used where permeability is intended.

PRESSURE, STATIC - The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal to the direction of flow. Usually expressed in inches water gage, when dealing with air.

PRESSURE TOTAL - The algebraic sum of the velocity pressure and the static pressure (with due regard to sign). In gas-handling systems these pressures are usually expressed in inches water gage. The sum of the static pressure and the velocity pressure.

GLOSSARY OF TERMS

TEMPERATURE, DEW-POINT - The temperature at which the condensation of water vapor in a space begins for a given state of humidity and pressure as the temperature of the vapor is reduced. The temperature corresponding to saturation (100 per cent relative humidity) for a given absolute humidity at constant pressure.

TWILL WEAVE - Warp yarns floating over or under at least two consecutive picks from lower left to upper right, with the point of intersection moving one yarn outward and upward or downward on succeeding picks, causing diagonal lines in the cloth.

VELOCITY HEAD - Same as velocity pressure. (See Pressure, Velocity).

VELOCITY OF APPROACH - The velocity of air (gas), feet per minute, normal to the face of the filter media.

VELOCITY TRAVERSE - A method of determining the average air velocity in a duct. A duct, round or rectangular, is divided into numerous sections of equal area. The velocity is determined in each area and the mean is taken of the sum.

REFERENCES

EPA - 650/2-74-058 7/74 (NTIS No. PB237117)

Applying Fabric Filtration To Coal-Fired Industrial Boilers
John D. McKenna

EPA - 650/2-74-058a 8/75 (NTIS No. PB245186)

Applying Fabric Filtration To Coal-Fired Industrial Boilers: A Pilot Scale Investigation
John D. McKenna, John C. Mycock and W. O. Lipscomb

EPA - 600/7-79-094 4/79 (NTIS No. PB299566)

Assessment of a High Velocity Fabric Filtration System Used to Control Fly Ash Emissions
John D. McKenna, John C. Mycock, K. D. Brandt and J. F. Szalay

COST CALCULATION METHODOLOGY

The total annualized cost is equal to the annual cost for operation and maintenance, plus the annualized capital cost and the depreciated capital investment, where the annualized capital costs are taxes, insurance and interest charges.

$$T = G + X + Y$$

where:

T = Total annualized cost

G = Annual costs for operation and maintenance

X = Annualized capital costs (taxes, insurance, interest)

Y = Depreciated capital investment

The annual operating costs for operation and maintenance of air pollution control equipment is the sum of the electrical costs, liquid consumption costs, fuel costs and maintenance costs.

$$G = A + B + C + D$$

where:

A = Electrical costs

B = Liquid consumption costs

C = Fuel costs

D = Maintenance costs

In the case of fabric filters for particulate collection, the liquid consumption costs and fuel costs are zero.

Therefore:

$$G = A + D$$

where:

$$A = \frac{0.7457}{6356E} \quad PHKS$$

$$D = MS$$

$$G = \left(\frac{0.7457}{6356E} \quad PHK + M\right) S$$

where:

S = Design Capacity of Fabric Filter in ACFM
P = Pressure Drop, Inches of Water
E = Fan Efficiency
0.7457 = A Constant (1 hp = 0.7457 KW)
H = Annual Operating Time in Hours
K = Power Cost, Dollars Per Kilowatt-Hour
M = Maintenance Cost, Dollars Per ACFM

The annualized capital costs are additive and normally treated as percentages of the total capital investment.

The depreciated capital investment is a function of the depreciation method chosen and the total capital investment.

Fabric Filter

Operating and Annualized Costs

Sample Calculations

Formula for calculating theoretical operating and annualized cost of control were taken from: Edminsten, N.G. and Bunyard, F.L., "A Systematic Procedure for Determining the Cost of Controlling Particulate Emissions from Industrial Sources", JAPCA, V20 N7, p. 446, July, 1970.

I. Fabric Filter Operating Cost:

Case - Teflon Felt at A/C = 5.8/1

$$G = S \left[\frac{0.7457}{6356E} \quad PHK + M\right]$$

Where: G = Theoretical Annual Cost for Operation and Maintenance

S = Design Capacity, ACFM

P = Pressure Drop, Inches of Water

E = Fan Efficiency, Assumed to be 60% (Expressed as 0.60)

0.7457 - A Constant, 1 Horsepower = .7457 Kilowatt

H = Annual Operating Time, 6240 Hours (24 Hours/Day X 5 Days/Week X 52 Weeks/Year = 6240 Hours/Year)

K = Power Costs, $/KWH

M = Maintenance Cost, $/ACFM (Based on 25% Bag Replacement Per Year)

In this case:

S = 70,000 ACFM

P = 3.4 Inches of Water

E = 60%

H = 6,240 Hours

K = $0.021/KWH

M = (No. of Bags in House X 25% Replacement Rate X Cost Per Bag) ÷ S

Sample Calculations

(Continued)

$$M = \frac{1080 \text{ Bags} \times .25 \times \$53/\text{Bag}}{70{,}000 \text{ ACFM}} = \$.20443/\text{ACFM}$$

Assuming a 60% fan efficiency reduces the above equation for G to:

$$G = S \quad (195.5 \times 10^{-6} \text{ PHK} + M)$$

Substituting the figures above yields:

$$G = 70{,}000 \left[(195.5 \times 10^{-6} \times 3.4 \times 6240 \times 0.021) + 0.20443\right]$$

$$= 70{,}000 \quad (.08710 + .20443)$$

$$= 70{,}000 \quad (.29153)$$

$$= 20{,}410 \quad \text{(Dollars)}$$

II. Total annualized cost of control is equal to the annual operating cost plus the annualized capital cost.

Annualized Capital Cost = 0.133 X Installed Costs

Assumptions:

1. Purchase and installation costs are depreciated over fifteen (15) years.

2. The straight line method of depreciation (6 2/3% per year) is used.

3. Other costs called capital charges are assumed to be equal to the amount of depreciation. Therefore, depreciation plus other capital charges amount to 13 1/3 percent of the initial capital costs of the equipment.

In this case: Teflon Felt at A/C = 5.8/1

Total Annualized Cost of Control = .133 X Installed Costs + Operating Costs

$$= \quad (.133 \times 153{,}700) \quad + \quad 20{,}410$$

$$= \quad 40{,}852 \quad \text{(Dollars)}$$

Figure R-5

△ Globe Albany 22.5 oz/yd^2 Woven Glass, 1 month on-stream time

□ Gore-Tex/Gore-Tex PTFE laminate[1], 1 yr on-stream time

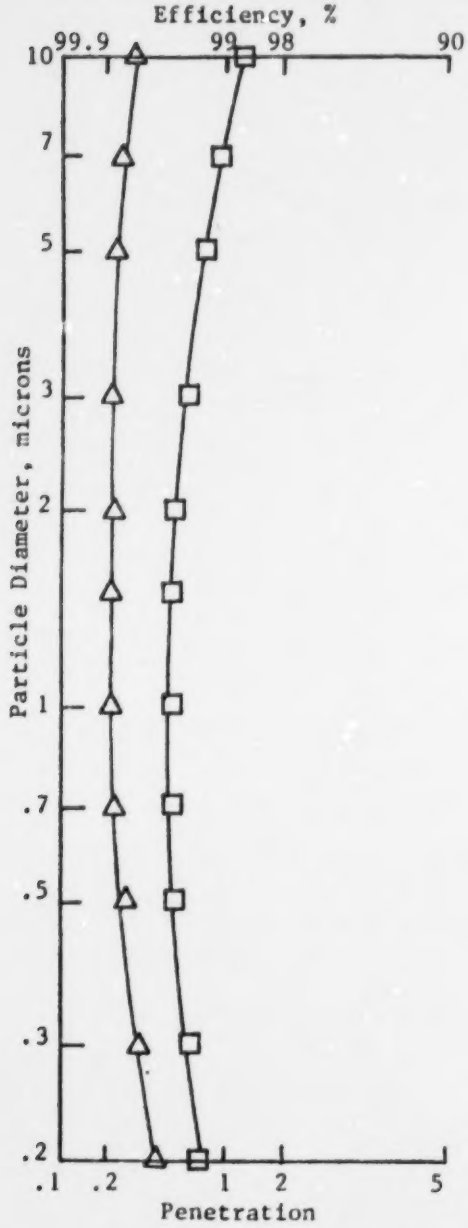


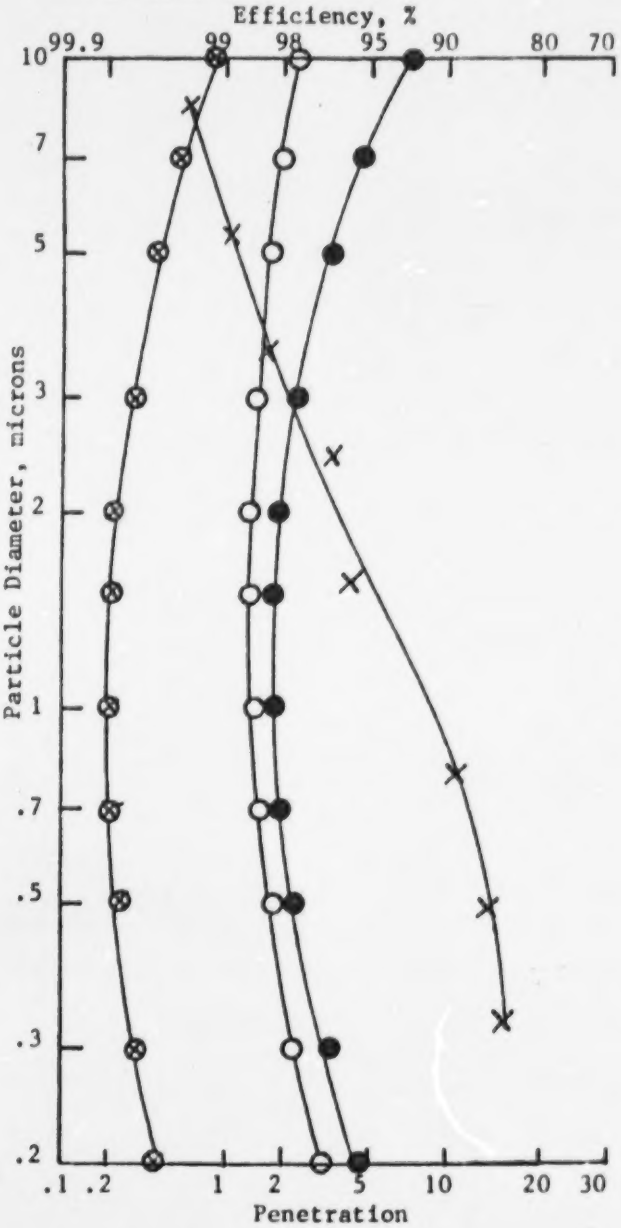
Figure R-6

○ Teflon Felt (Before Cyclone*), 2 yr on-stream time

● Teflon Felt (After Cyclone*), 2 yr on-stream time

⊗ Teflon Felt, 1 yr on-stream time

× Teflon Felt (Pilot Study Data), 1 month on-stream time



Particle Size Removal Efficiencies

*A cyclone was installed on inlet to the Teflon Felt house in July 1978.
[1]Data from 1977; no probe and nozzle washes were collected.

Table R-5

Coal Analysis

December 1977

	As Received	Dry
Moisture	6.87 %	
Ash	14.35 %	15.41 %
Volatile	30.12 %	32.34 %
Fixed Carbon	48.66 %	52.25 %
Sulfur	0.67 %	0.72 %
Carbon	65.49 %	70.32 %
Hydrogen	4.21 %	4.52 %
Oxygen & Nitrogen	8.41 %	9.03 %

Heat Value	As Received	Dry	MAF
BTU/lb.	11560	12412	14674

Table R-6

Outlet Characterization by Andersen Impactor
(Particle Sizing)

		Particle Diameter, Microns								
		Stage								
Test #	Date	1	2	3	4	5	6	7	8	Back-Up Filter
TEFLON FELT HOUSE										
56	5/10/78	>11.78	8.27	5.09	3.58	2.33	1.08	.65	.48	<.48
58	5/11/78	>11.37	7.98	4.92	3.46	2.25	1.04	.63	.46	<.46
59	5/11/78	>11.37	7.98	4.92	3.46	2.25	1.04	.63	.46	<.46
60	10/3/78	>11.10	7.79	4.80	3.38	2.20	1.02	.61	.44	<.44
	MEAN	>11.40	8.00	4.93	3.47	2.26	1.04	.63	.46	<.46
GLOBE ALBANY 22.5 OZ./YD.^{2} WOVEN GLASS HOUSE										
63	9/21/78	>11.12	7.80	4.80	3.38	2.20	1.02	.61	.44	<.44
64	9/21/78	>11.37	7.98	4.91	3.46	2.25	1.04	.62	.46	<.46
66	11/15/78	>10.18	7.14	4.39	3.09	2.01	.92	.55	.40	<.40
	MEAN	>10.89	7.64	4.70	3.31	2.15	.99	.59	.43	<.43

(continued)

Table R-6 (continued)

Outlet Characterization by Andersen Impactor
(Particle Sizing)

	Cumulative % Less Than Size Stated								
	Stage								
Test #	1	2	3	4	5	6	7	8	Back-Up Filter
TEFLON FELT HOUSE									
56	62.27	50.68	41.46	33.80	25.27	16.52	10.37	7.14	-
58	60.57	51.69	40.22	29.83	22.75	16.46	10.28	6.59	-
59	50.78	43.81	34.09	26.26	16.18	9.08	4.93	2.69	-
65	47.25	33.10	25.32	19.50	14.61	10.23	6.45	3.74	-
GLOBE ALBANY 22.5 OZ./YD.^{2} WOVEN GLASS HOUSE									
63	47.43	39.06	31.76	24.04	17.82	12.45	8.59	4.08	-
64	51.19	40.95	31.76	25.82	20.48	13.80	8.31	2.38	-
66	57.15	48.02	39.09	33.74	25.60	17.76	11.61	6.06	-

(continued)

Table R-6 (continued)

Outlet Characterization by Andersen Impactor
(Particle Sizing)

	Loading, Grains/DSCF									
					Stage				Back-Up	
Test #	1	2	3	4	5	6	7	8	Filter	Total
TEFLON FELT HOUSE										
56	.01434	.00441	.00350	.00291	.00324	.00333	.00234	.00122	.00271	.03800
58	.01328	.00299	.00386	.00350	.00238	.00212	.00208	.00124	.00222	.03367
59	.01751	.00248	.00346	.00279	.00358	.00253	.00148	.00080	.00096	.03559
65	.01500	.00402	.00221	.00165	.00142	.00122	.00107	.00077	.00106	.02842
Mean	.01503	.00348	.00326	.00271	.00266	.00230	.00174	.00101	.00174	.03393
GLOBE ALBANY 22.5 OZ./YD.^{2} WOVEN GLASS HOUSE										
63	.00289	.00046	.00040	.00042	.00034	.00029	.00021	.00025	.00022	.00548
64	.00395	.00083	.00074	.00048	.00043	.00054	.00044	.00048	.00019	.00808
66	.00274	.00058	.00057	.00034	.00052	.00050	.00039	.00035	.00039	.00638
Mean	.00319	.00062	.00057	.00041	.00043	.00044	.00035	.00036	.00027	.00664

Table R-7

Particle Size Removal Efficiencies

Particle Diameter, microns	Globe Albany 22.5 oz/yd^2 Woven Glass[1,2]		Teflon Felt[1] Before Cyclone[3,4]		Teflon Felt[1] After Cyclone[3,5]	
	Penetration	Efficiency	Penetration	Efficiency	Penetration	Efficiency
.200	.0041	99.59%	.0311	96.89%	.0474	95.26%
.300	.0033	99.67	.0232	97.68	.0316	96.84
.500	.0028	99.72	.0175	98.25	.0220	97.80
.700	.0025	99.75	.0153	98.47	.0190	98.10
1.000	.0023	99.77	.0140	98.60	.0175	98.25
1.500	.0022	99.78	.0133	98.67	.0176	98.24
2.000	.0022	99.78	.0133	98.67	.0188	98.12
3.000	.0022	99.78	.0141	98.59	.0226	97.74
5.000	.0024	99.76	.0165	98.35	.0330	96.70
7.000	.0026	99.74	.0194	98.06	.0464	95.36
10.000	.0029	99.71	.0240	97.60	.0718	92.82
20.000	.0040	99.60	.0416	95.84	.2113	78.87
Overall	.0033	99.67	.0157	98.43	.0612	93.88

Particle Diameter, microns	Teflon Felt[1,9] (Data from First Year of Full-Scale Project)[10]		Particle Diameter, microns	Teflon Felt[6,7] (Data from Pilot Study)[8]	
	Penetration	Efficiency		Penetration	Efficiency
.200	.0042	99.58%	>8.38	.0063	99.37%
.300	.0031	99.69	5.29	.0106	98.94
.500	.0024	99.76	3.55	.0163	98.37
.700	.0021	99.79	2.47	.0350	96.50
1.000	.0021	99.79	1.57	.0400	96.00
1.500	.0021	99.79	.79	.1057	89.43
2.000	.0023	99.77	.49	.1333	96.67
3.000	.0028	99.72	.33	.1549	84.51
5.000	.0040	99.60	<.33	.1235	87.65
7.000	.0055	99.45			
10.000	.0083	99.17	Overall	.0183	98.17
20.000	.0219	97.81			
Overall	.0198	98.02			

(continued)

Table R-7, (continued)

Particle Diameter, microns	Gore-Tex[1,9,11] (Data from First Year of Full-Scale Project)[10] Penetration	Efficiency
.200	.0075	99.25%
.300	.0063	99.37
.500	.0054	99.46
.700	.0051	99.49
1.000	.0050	99.50
1.500	.0051	99.49
2.000	.0054	99.46
3.000	.0061	99.39
5.000	.0077	99.23
7.000	.0094	99.06
10.000	.0122	98.78
20.000	.0223	97.77
Overall	.0101	98.99

(1) Linear least squares data fit

(2) Approx. 1 month on-stream time; mean G/C ratio 5.6/1

(3) A cyclone was installed on inlet to Teflon Felt house in July 1978.

(4) Approx. 18 months on-stream time; mean G/C ratio 5.4/1

(5) Approx. 2 years on-stream time; mean G/C ratio 5.4/1

(6) No probe and nozzle washes were collected.

(7) Approx. 1 month on-stream time; G/C ratio 5.4/1

(8) McKenna, J. D. et al, "Applying Fabric Filtration to Coal-Fired Industrial Boilers: A Pilot Scale Investigation", U. S. Dept. of Commerce, NTIS, Springfield, Va. 21161, PB-245-186.

(9) Approx. 1 year on-stream time; mean G/C ratio 5.6/1

(10) McKenna, J. D. et al, "Assessment of a High Velocity Fabric Filtration System Used to Control Fly Ash Emissions", U. S. EPA, Office of Research and Development, Washington, D. C. 20460, EPA-600/7-79-094.

(11) No probe and nozzle washes were collected; G/C ratio 5.6/1

TABLE R-8

METHOD 5 - BAGHOUSE #1 INLET

Concord, NC			Travelers Rest, SC		
Run No.	Date	GR/SCF	Run No.	Date	GR/SCF
3	1/4/77	0.3853	75	2/25/80	0.7509
6	1/7/77	0.3947	76	2/26/80	0.4064
9	4/26/77	0.7374	99	10/8/80	0.7613
12	4/28/77	0.5235	97	10/2/80	0.2048
20	6/16/77	0.7878	93	9/19/80	0.6295
21	6/17/77	0.3846	92	9/18/80	0.3982
36	1/27/78	0.5028	Avg.		0.5252
38	1/27/78	0.4741			
40	1/27/78	0.3215			
Avg.		0.5013			

TABLE R-9

METHOD 5 - BAGHOUSE #1 OUTLET

Concord, NC			Travelers Rest, SC		
Run No.	Date	GR/SCF	Run No.	DATE	GR/SCF
1	12/16/76	0.0337	77	3/10/80	.0181
9	4/26/77	0.0912	78	3/11/80	.0269
30	9/1/77	0.0175	80	3/13/80	.0546
31	9/1/77	0.0132	81	3/20/80	.1305
32	9/1/77	0.0279	82	3/20/80	.0727
37	1/27/78	0.0266	83	3/20/80	.0962
39	1/27/78	0.0235	84	3/21/80	.0761
41	1/27/78	0.0185	Avg. .0679		
42	2/22/78	0.0509			
48	3/30/78	0.0087			
49	3/31/78	0.0177			
50	4/6/78	0.0200			
51	4/11/78	0.0247			
52	4/11/78	0.0186			
53	5/8/78	0.0429			
54	5/9/78	0.0716			
55	5/10/78	0.0530			
Avg. 0.0330					

TABLE R-10

METHOD 5 - BAGHOUSE 2

INLET			OUTLET		
Run No.	Date	GR/SCF	Run No.	Date	GR/SCF
4	1/6/77	0.4223	2	12/17/76	0.0330
5	1/6/77	0.3999	7	1/20/77	0.1230
11	4/27/77	0.4593	11	4/27/77	0.0263
Avg.		.4272	12	4/28/77	0.0598
			Avg.		.0605